TULANE STUDIES IN ZOOLOGY

VOLUME 12
1964-1965

MARINE BIOLOGICAL LABORATORY
WOODS HOLE
LIBRARY
MASS.

TULANE UNIVERSITY
NEW ORLEANS

TULANE STUDIES IN ZOOLOGY is devoted primarily to the zoology of the waters and adjacent land areas of the Gulf of Mexico and the Caribbean Sea. Each number is issued separately and contains an individual monographic study, or several minor studies. As volumes are completed, title pages and tables of contents are distributed to institutions receiving the entire series.

Manuscripts submitted for publication are evaluated by the editor or associate editor and by an editorial committee selected for each paper. Contributors need not be members of the Tulane University faculty.

The editors of *Tulane Studies in Zoology* recommend conformance with the principles stated in chapters I and II (only) of the *Style Manual for Biological Journals*, 2nd ed., published in 1964 by the American Institute of Biological Sciences, Washington, D. C.

Manuscripts should be submitted on good paper, as original typewritten copy, double-spaced, and carefully corrected. Two copies, carbon or other suitable reproduction, must accompany the original to expedite editing and assure more rapid publication. Legends for figures should be prepared on a separate page. Illustrations should be proportioned for one or two column width reproductions and should allow for insertion of legend if occupying a whole page.

An abstract not exceeding three percent of the length of the original article must accompany each manuscript submitted. This will be transmitted to *Biological Abstracts* and any other abstracting journal specified by the writer.

The editors also recognize the policy adopted by the Federal Council for Science and Technology, and endorsed by the Conference of Biological Editors, that page charges for publication of scientific research results in scientific journals will be budgeted for and paid as a necessary part of research costs under Federal grants and contracts. Accordingly, writers crediting research grant support in their contributions will be requested to defray publication costs if allowable under the terms of their specific awards.

Illustrations and tabular matter in excess of 20 percent of the total number of pages may be charged to the author, the levy applied being the excess above 10-point typesetting costs.

Exchanges are invited from institutions publishing comparable series but subscriptions are available if no exchange agreement can be effected. Separate numbers or volumes can be purchased by individuals, but subscriptions are not accepted. Remittance should accompany orders from individuals. Authors may obtain separates of their articles at cost.

Address all communications concerning manuscripts and editorial matters to the editor; Communications concerning exchanges, and orders for individual numbers to the Meade Natural History Library.

When citing this series authors are requested to use the following abbreviations: *Tulane Stud. Zool.*

Price for this volume: $3.50.

Harold A. Dundee, *Editor*
Gerald E. Gunning, *Associate Editor*
Department of Biology,
Tulane University,
New Orleans, Louisiana 70118, U.S.A.

Harold A. Dundee, *Director*
Meade Natural History Library,
Tulane University,
New Orleans, Louisiana 70118, U.S.A.

James R. Reed, Jr.
Assistant to the Editors

CONTENTS OF VOLUME 12

NUMBER PAGE

1. A NEW BRANCHIOBDELLID (ANNELIDA) FROM COSTA RICA
Perry C. Holt 1

THE RIVER CRABS OF COSTA RICA, AND THE SUBFAMILIES OF THE PSEUDOTHELPHUSIDAE
Alfred E. Smalley 5

MYSIDOPSIS ALMYRA, A NEW ESTUARINE MYSID CRUSTACEAN FROM LOUISIANA AND FLORIDA
Thomas E. Boman 15

2. AGE DETERMINATION OF THE COTTON RAT *(SIGMODON HISPIDUS)*
Robert K. Chipman 19

DIGENETIC TREMATODES OF MARINE FISHES FROM APALACHEE BAY, GULF OF MEXICO
Fuad M. Nahhas and Robert B. Short 39

3. HISTOLOGY, DEVELOPMENT, AND INDIVIDUAL VARIATION OF COMPLEX MUROID BACULA
Andrew A. Arata, Norman C. Negus, and Martha Sapp Downs 51

ETHEOSTOMA DITREMA, A NEW DARTER OF THE SUBGENUS *OLIGOCEPHALUS* (PERCIDAE) FROM SPRINGS OF THE ALABAMA RIVER BASIN IN ALABAMA AND GEORGIA
John S. Ramsey and Royal D. Suttkus 65

PARASITES FROM LOUISIANA CRAYFISHES
Franklin Sogandares-Bernal 79

A NEW SUBSPECIES OF THE CRAWFISH *ORCONECTES LEPTOGONOPODUS* FROM THE OUACHITA RIVER DRAINAGE IN ARKANSAS
J. F. Fitzpatrick, Jr. 87

4. ECOLOGICAL DISTRIBUTION AND ACTIVITY PERIODS OF BATS OF THE MOGOLLON MOUNTAINS AREA OF NEW MEXICO AND ADJACENT ARIZONA
Clyde Jones 93

ETHEOSTOMA (OLIGOCEPHALUS) NUCHALE, A NEW DARTER FROM A LIMESTONE SPRING IN ALABAMA
William Mike Howell and Richard Dale Caldwell 101

EARLY DEVELOPMENTAL STAGES OF THE ROCK SHRIMP, *SICYONIA BREVIROSTRIS* STIMPSON, REARED IN THE LABORATORY
Harry L. Cook and M. Alice Murphy 109

FISHES TAKEN IN MONTHLY TRAWL SAMPLES OFFSHORE OF PINELLAS COUNTY, FLORIDA, WITH NEW ADDITIONS TO THE FISH FAUNA OF THE TAMPA BAY AREA
Martin A. Moe, Jr. and George T. Martin 129

Printed in the U.S.A.
at New Orleans, by
HAUSER-AMERICAN

TULANE STUDIES IN ZOOLOGY

Volume 12, Number 1 August 21, 1964

A NEW BRANCHIOBDELLID (ANNELIDA) FROM COSTA RICA

PERRY C. HOLT,
DEPARTMENT OF BIOLOGY
AND
VIRGINIA AGRICULTURAL EXPERIMENT STATION,
VIRGINIA POLYTECHNIC INSTITUTE,
BLACKSBURG, VIRGINIA p. 1

THE RIVER CRABS OF COSTA RICA, AND THE SUBFAMILIES OF THE PSEUDOTHELPHUSIDAE

ALFRED E. SMALLEY,
DEPARTMENT OF ZOOLOGY, TULANE UNIVERSITY,
NEW ORLEANS, LOUISIANA p. 5

MYSIDOPSIS ALMYRA, A NEW ESTUARINE MYSID CRUSTACEAN FROM LOUISIANA AND FLORIDA

THOMAS E. BOWMAN,
DIVISION OF MARINE INVERTEBRATES,
SMITHSONIAN INSTITUTION,
WASHINGTON, D. C. 20560 p. 15

Marine Biological Laboratory
LIBRARY
JUN 16 1965
WOODS HOLE, Mass.

TULANE UNIVERSITY
NEW ORLEANS

TULANE STUDIES IN ZOOLOGY is devoted primarily to the zoology of the waters and adjacent land areas of the Gulf of Mexico and the Caribbean Sea. Each number is issued separately and contains an individual monographic study, or several minor studies. As volumes are completed, title pages and tables of contents are distributed to institutions exchanging the entire series.

Manuscripts submitted for publication are evaluated by the editor or associate editor and by an editorial committee selected for each paper. Contributors need not be members of the Tulane University faculty.

The editors of *Tulane Studies in Zoology* recommend conformance with the principles stated in chapters I and II (only) of the *Style Manual for Biological Journals* published in 1960 by the American Institute of Biological Sciences, Washington, D. C.

The editors also recognize the policy adopted by the Federal Council for Science and Technology, and endorsed by the Conference of Biological Editors, that page charges for publication of scientific research results in scientific journals will be budgeted for and paid as a necessary part of research costs under Federal grants and contracts. Accordingly, writers crediting research grant support in their contributions will be requested to defray publication costs if allowable under the terms of their specific awards.

Illustrations and tabular matter in excess of 20 percent of the total number of pages may be charged to the author, the levy applied being the excess above 10-point typesetting costs.

Manuscripts should be submitted on good paper, as original typewritten copy, double-spaced, and carefully corrected. Two carbon copies in addition to the original will help expedite editing and assure more rapid publication.

An abstract not exceeding three percent of the length of the original article must accompany each manuscript submitted. This will be transmitted to *Biological Abstracts* and any other abstracting journal specified by the writer.

Separate numbers or volumes may be purchased by individuals, but subscriptions are not accepted. Remittance should accompany orders from individuals. Authors may obtain copies for personal use at cost.

Address all communications concerning manuscripts and editorial matters to the editor; communications concerning exchanges, and orders for individual numbers to the Director, Meade Natural History Library.

When citing this series authors are requested to use the following abbreviations: *Tulane Stud. Zool.*

Price for this number: $0.50.

Harold A. Dundee, *Editor*
Gerald E. Gunning, *Associate Editor*
Department of Zoology,
Tulane University,
New Orleans, Louisiana 70118, U.S.A.

Royal D. Suttkus, *Director*
Meade Natural History Library,
Tulane University,
New Orleans, Louisiana 70118, U.S.A.

Francis L. Rose,
Assistant to the Editors

TULANE STUDIES IN ZOOLOGY

Volume 12, Number 1 August 21, 1964

A NEW BRANCHIOBDELLID (ANNELIDA) FROM COSTA RICA

PERRY C. HOLT,
Department of Biology
and
Virginia Agricultural Experiment Station,
Virginia Polytechnic Institute,
Blacksburg, Virginia

ABSTRACT

A new branchiobdellid, *Cambarincola smalleyi*, from freshwater crabs of the family Pseudothelphusidae in Costa Rica is described. A somewhat primitive member of the genus, this species is assumed to be a southern survivor of a Pleistocene migration of cambarine crawfishes and their epizoic commensals. It is hypothesized that the branchiobdellids survived in Costa Rica by passing from their former hosts to the winners of the interglacial or post-Pleistocene competition between crawfishes and crabs.

Branchiobdellid annelid worms, usually found as epizoic commensals on freshwater crawfishes of the family Astacidae, have been known from Mexico for some time (Rioje, 1940, 1943). They recently have been recorded from hosts other than astacid crawfishes (Hobbs and Villalobos F., 1958; Holt, 1963). The finding of them on freshwater crabs of the family Pseudothelphusidae in Costa Rica by Alfred E. Smalley of Tulane University, is, nonetheless, worthy of note. First, this discovery adds another to the rapidly increasing list of crustacean families which serve as hosts for the branchiobdellids. In addition, the southward extension of their range from the Isthmus of Tehuantepec in Mexico through approximately seven degrees of latitude to the highlands of Costa Rica is of some zoogeographical interest.

I am grateful to Dr. Smalley for making the four mature worms which he recovered from specimens of *Pseudothelphusa tumimanus* Rathbun (Pseudothelphusidae) available to me for study and take pleasure in naming the new species of the genus *Cambarincola* which they represent in his honor.

The procedures I use in the study of branchiobdellids have been described elsewhere (Holt, 1960). My studies are supported by a grant, NSF-GB372, from the National Science Foundation.

Cambarincola **smalleyi**, n. sp.
(Figs. 1-4)

Diagnosis. Medium-sized members of the genus; head, approximately equal in diameter to that of segment I and the sucker, showing external evidence of being composed of four segments; prosomites of body segments not appreciably greater in diameter than metasomites; jaws homodont and isomorphic, dental formula 6/6. Male reproductive system: the prostate about two-thirds the size of the spermiducal gland in length and diameter and histologically different from the latter, the prostate lacking an ental

EDITORIAL COMMITTEE FOR THIS PAPER:

G. E. GATES, Emeritus Professor and Visiting Professor, University of Maine, Orono, Maine

WALTER J. HARMAN, Chairman, Department of Zoology, Louisiana State University, Baton Rouge, Louisiana

WILLIAM R. MURCHIE, Professor of Zoology, Flint College, University of Michigan, Flint, Michigan

bulb; the spermiducal gland without deferent lobes; the bursa elongate pyriform in shape. Female reproductive system: spermatheca with a long ectal duct and an ental process.

Description. Since only four specimens of *Cambarincola smalleyi* are known, measurements are of little value. The type specimen, however, as some indication of the size of these animals, has the following dimensions: *total length,* 2.82 mm; *head length,* 0.43 mm; *head diameter,* 0.29 mm; *diameter, segment I,* 0.30 mm; *diameter, segment VI,* 0.51 mm; *diameter, sucker,* 0.39 mm. The smallest specimen is 1.93 mm long.

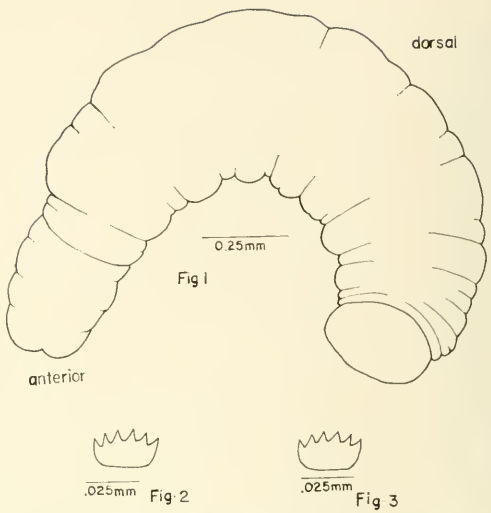
The worms are somewhat corpulent in appearance; the greatest diameter of the holotype is one-sixth the total body length. The prosomites are not markedly greater in diameter than the metasomites, the body wall lacking the supernumerary muscles which produce this condition in some branchiobdellids. The sucker is of usual appearance and somewhat greater in diameter than the head or segment I.

The head shows obvious external signs of being composed of four segments (Fig. 1). Other branchiobdellids are known to have four vascular commissures in the head, but in *C. smalleyi* these commissures are readily apparent in the specimens mounted entire. The peristomium is, as usual, divided into dorsal and ventral "lips"; each lip is subdivided by a slight median emargination. No oral papillae are present.

The jaws (Figs, 2 and 3) are unusual. The upper and lower jaws are similar in size and shape and the number of teeth (six) is the same for each jaw. The teeth, furthermore, are subequal in size and their points form a gently curved arc in dorsal view. The jaws are sub-rectangular in dorsal view. They contrast, then, in these respects, with the triangular jaws with fewer teeth of most species of the genus. The dental formula of 6 6 is diagnostic of *C. smalleyi.*

The anterior nephridiopore, located as usual for the genus, is unusually prominent. The "bladder" and outlet duct formed by the junction of the two nephridia are thick-walled and glandular in appearance. Whether or not this reflects a real difference or the accidents of preservation cannot be determined from the material available.

The prostate is composed of large vacuolated glandular cells, the spermiducal gland



Figures 1-3. *Cambarincola smalleyi,* n. sp. 1. Outline drawing of type specimen. 2. Dorsal jaw, paratype. 3. Ventral jaw, paratype.

of more densely granular cells, but the prostatic ental bulb is absent. The short, relatively thick, differentiated prostate without an ental bulb, a condition not described for any other branchiobdellid, is characteristic of *C. smalleyi.*

The spermiducal gland is perhaps somewhat smaller in proportion to the total size of the animal than in most other species of the genus, but otherwise is not remarkable. The same statement can be made about the other organs of the male reproductive system.

A clitellum is present on segments VI and XII. The spermatheca has a rather long ectal duct and the spermathecal bulb has a small, but distinct, ental process (Fig. 4).

Type locality. Rio Hondura, eight miles north of San Jeronimo de Moravia, San José Province, Costa Rica.

Host. Pseudothelphusa tumimanus Rathbun.

Disposition of types. The holotype, U. S. N. M. No. 30940 and one paratype, U. S. N. M. No. 30941 are deposited in the collections of the Division of Marine Invertebrates, United States National Museum. One paratype is in the collection of Dr. Smalley at Tulane University and the remaining one is retained in my collections kept at the Virginia Polytechnic Institute (PCH 1702).

Distribution. Cambarincola smalleyi is known only from the type locality.

Remarks. *Cambarincola smalleyi* most closely resembles *C. vitrea* Ellis, 1919, in jaw structure but differs in the larger number of teeth borne by the jaws of the former and in the fact that the same number of teeth is present on each jaw. The general body form is like that of many species of the genus, differing in the more obvious signs of segmentation of the head. The male reproductive system in the histologically differentiated prostate is like that of Hoffman's (1963) *philadelphica* section of the genus, which includes *C. vitrea,* but differs in the absence of a prostatic bulb. One can speculate that *C. smalleyi* is related in a greater or lesser degree to *C. vitrea,* a species which is widespread in the mid-continental plains region of the United States, or to *C. mesochorea* Hoffman, 1963, likewise a mid-continental species. *C. mesochorea* has an undifferentiated prostate without an ental bulb, but has an ental spermathecal process, present in *C. smalleyi* and absent in *C. vitrea.*

Cambarincola smalleyi extends the known range of branchiobdellids almost 500 miles southward from southern Mexico to Costa Rica. Presumably it represents a montane survivor of a population representing the pre-Pleistocene North American fauna which moved southward during one of the Pleistocene glaciations. The species must have reached Costa Rica more recently than the late Miocene or early Pliocene closing of the Central American water gaps, if these gaps existed as is generally believed. The northern, temperate distribution of branchiobdellids would argue against them being a part of the Neotropical Cenozoic fauna of North America.

Though the jaws of *C. smalleyi* are presently thought to reflect a primitive branchiobdellid condition (Ellis, 1919) and the segmentation of the head is undoubtedly primitive, the species does not appear markedly primitive in other respects. The most reasonable conclusion would seem to be that it is a descendant of an already relatively advanced cambarincolid, pre-Pleistocene stock intermediate between *Cambarincola mesochorea* and *C. vitrea.*

Finally, some notice must be taken of the host of *C. smalleyi.* Presently, branchiobdellids are known from astacine, cambaroidine, and cambarine crawfishes, isopods of the genus *Asellus* (Holt, 1963), and grapsid crabs (Hobbs and Villalobos F., 1958).

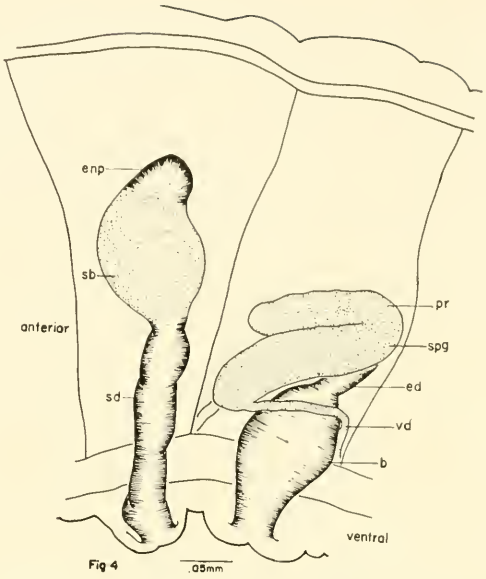


Figure 4. *Cambarincola smalleyi,* lateral view of reproductive systems of type specimen. Abbreviations: *b,* bursa; *ed,* ejaculatory duct; *enp,* ental process of spermatheca; *pr,* prostate; *sb,* bulb of spermatheca; *sd,* ectal duct of spermatheca; *spg,* spermiducal gland; *vd,* vas deferens.

Their occurrence on the tropical, freshwater, pseudothelphusid crabs takes them considerably beyond the range of the cambarine crawfishes which reach their southern limits in the Guatemalan highlands. Unquestionably, branchiobdellids are primarily commensals of astacid decapods, but no longer can be assumed to be confined to these hosts. Yet cambarine crawfishes must have carried them to Costa Rica, lost in competition with the tropical crabs, and passed their commensals to their conquerors.

The hypothesis that the branchiobdellids passed from crawfishes to crabs in southern Mexico and hence by repeated transfers and migrations southward to other crabs in Costa Rica may be, on the contrary, the correct explanation: it seems to me less likely.

Summary. A new branchiobdellid, *Cambarincola smalleyi,* from freshwater crabs of the family Pseudothelphusidae in Costa Rica is described. Although a somewhat primitive member of the genus, it is not markedly so, and is assumed to be a southern survivor of a Pleistocene migration of cambarine crawfishes and their epizoic commensals. The branchiobdellids presumably survived in

Costa Rica by passing from their former hosts to the winners of the interglacial or post-Pleistocene competition between crawfishes and crabs.

References Cited

Ellis, Max M. 1919. The branchiobdellid worms in the collections of the United States National Museum, with descriptions of new genera and new species. *Proc. U. S. Nat. Mus.* **55**: 241-265.

Hobbs, Horton H., Jr. and Alejandro Villalobos F. 1958. The exoskeleton of a freshwater crab as a microhabitat for several invertebrates. *Virginia J. Sci. (N. S.)* **9**: 395-396.

Hoffman, Richard L. 1963. A revision of the North American annelid worms of the genus *Cambarincola* (Oligochaeta: Branchiobdellidae). *Proc. U. S. Nat. Mus.* **114**: 271-371.

Holt, Perry C. 1949. A comparative study of the reproductive systems of *Xironogiton instabilius instabilius* (Moore) and *Cambarincola philadelphica* (Leidy) (Annelida, Oligochaeta, Brancniobdellidae). *J. Morph.* **84**: 535-572.

———— 1960. The genus *Ceratodrilus* Hall (Branchiobdellidae, Oligochaeta), with the description of a new species. *Virginia J. Sci. (N. S.)* **11**: 53-77.

———— 1963. A new branchiobdellid (Branchiobdellidae: Cambarincola). *J. Tennessee Acad. Sci.* **38**: 97-100.

Rioja, Enrigue, 1940. Estudios Hidrobiologicos II. Datos sobre los Branchiobdellidae de Xochimilco, Zempoala y Texcoco. *Anales del Instituto de Biologia* **11 (1)**: 249-253.

———— 1943. Estudios Hidrobiologicos IX. Anotaciones sobre branquiobdelidos Mexicanos. *Anales del Instituto de Biologia* **14(2)**: 541-545.

THE RIVER CRABS OF COSTA RICA, AND THE SUBFAMILIES OF THE PSEUDOTHELPHUSIDAE

ALFRED E. SMALLEY,
Department of Zoology, Tulane University, New Orleans, Louisiana

Abstract

The Costa Rican river crabs of the family Pseudothelphusidae are reviewed and their gonopods described. Two subfamilies are recognized in the family Pseudothelphusidae; the new subfamily **Epilobocerinae** for *Epilobocera*, and Pseudothelphusinae for the remaining four genera. *Epilobocera fuhrmanni* is a *Pseudothelphusa*. New subgenera proposed for *Pseudothelphusa* are: **Achlidon**, for *P. agrestis;* **Allacanthus**, for *P. pittieri;* **Megathelphusa**, for *P. magna* and *P. richmondi;* **Ptychophallus**, for *P. tristani, P. montana, P. tumimanus, P. exilipes*, and *P. xantusi. P. convexa* is relegated to the synonymy of *P. montana*.

I. Introduction

The American river crabs are an important component of the fauna of tropical fresh waters. There are numerous species, most of which have restricted ranges. Taxonomically, the river crabs have been neglected in spite of the many interesting systematic and zoogeographic problems posed by them. Most of the Pseudothelphusidae were described by Rathbun, who also produced the most recent monograph of the family (Rathbun, 1905). Since that time, studies have been sporadic, usually incidental to other research, or included in faunistic papers. Furthermore, earlier students did not recognize the importance of the male pleopods (gonopods) in classification. Rathbun was inconsistent in the use of gonopod characters. Sometimes she provided good figures, but at other times she ignored the gonopods, even when the description was based on a male.

Rathbun was well aware of the inadequacy of using the carapace for taxonomic distinctions in the genus *Pseudothelphusa,* and also realized the specific distinctiveness of the gonopods, but nevertheless chose to base her keys and descriptions on non-gonopodal features. As a result, many descriptions are based on females, although species of *Pseudothelphusa* should never be described from females alone. Even if a species can be distinguished without using the gonopods, its relationships to other species and genera will remain unknown if this practice is followed.

In this paper, the five genera of the Pseudothelphusidae are divided into two subfamilies and the Costa Rican *Pseudothelphusa* into subgenera on the basis of gonopod structure. In addition, supplementary descriptions are given for the Costa Rican species.

There are types of all the Costa Rican species in the U. S. National Museum.

II. Collection Localities

Since most of the Pseudothelphusidae have restricted ranges, the localities where they are collected assume considerable importance. All of the Pseudothelphusidae known from Costa Rica were described by Rathbun (1893, 1896, 1898), from specimens provided by various collectors. The locality data supplied by these collectors are inadequate, usually including the name of the nearest village or town and the altitude, but never the province. Since finding the localities where these collections were made

Editorial Committee for this Paper:

Fenner A. Chace, Jr., Senior Scientist, Department of Zoology, United States National Museum, Washington, D.C.

Dr. L. B. Holthuis, Rijksmuseum van Naturlijke Historie, Raamsteeg 2, Leiden, The Netherlands

Harold E. Vokes, Professor and Chairman, Department of Geology, Tulane University, New Orleans, Louisiana

proved to be a difficult task, the results of my search are listed below. Sr. Don Salvador Jiménez-Canossa was most helpful in resolving difficult problems. The gazetteer by Selander and Vaurie (1962) is very useful, and would have greatly lightened my task had it been available sooner.

Aguabuena. Puntarenas Prov., near the Panamanian border, 8° 44′ N, 82° 56′ W.

Boruca. Puntarenas Prov., 9° 01′ N, 83° 21′ W.

Cachí. Cartago Prov., 9° 49′ N, 83° 48′ W.

Cariblanco. Heredia Prov., 10° 10′ N, 84° 10′ W.

Chemin de Carrillo. Junction of San José, Cartago, and Limón Provinces, 10° 10′ N, 83° 57′ W.

El Coronel. Border of San José and Cartago Provinces, on the Rio Sucio, 10° 7′ N, 83° 55′ W.

Java. Selander and Vaurie list a "Quebrada de Java," Puntarenas Prov., 8° 52′ N, 83° 01′ W.

La Palma. There are several "La Palmas" in Costa Rica. According to the altitude of 1500 meters, the one cited by Rathbun is probably Alto La Palma, San José Prov., 10° 03′ N, 83° 58′ W.

Pacaca, Rodeo. Pacaca is an older name for Villa Colon: Rodeo is probably the name for a farm or ranch. San José Prov., 9° 56′ N, 84° 16′ W.

Palmar. Palmar Norte or Palmar Sur, Puntarenas Prov., 8° 57′ N, 83° 27′ W.

Pozo Azul. Guanacaste Prov., 10° 12′ N, 84° 56′ W.

Rio Maria Aguilar. A tributary of the Rio Virilla, probably near the city of San José, San José Prov., 9° 56′ N, 84° 05′ W.

Rio Torres. Also a tributary of the Rio Virilla, probably near San José (see previous item).

San Carlos. A region, or district, in Alajuela Province, drained by the Rio San Carlos.

Santa Clara Jiménez. Heredia Prov., 10° 13′ N, 83° 43′ W.

Santa Domingo, Gulf of Dulce. Puntarenas Prov., 8° 32′ N, 83° 17′ W.

Surubres, near San Mateo, Alajuela Prov., 9° 56′ N, 84° 30′ W.

La Flor, Torito. Cartago Prov., 9° 53′ N, 83° 50′ W.

III. Key to the species of Costa Rican Pseudothelphusidae

The following key is based principally on gonopod morphology. There are no fundamental differences between the gonopods of *Pseudothelphusa* and *Potamocarcinus,* and the gonopod characteristics of *Potamocarcinus* included in the key should not be considered of generic importance. Terminology follows Smalley (1964).

1. Antero-lateral teeth of carapace large and spiniform; ventral border of front of carapace not visible from above; marginal process of gonopod extending beyond apex. ..... *Potamocarcinus nicaraguensis*
   Antero-lateral teeth small or minute; ventral margin of front visible from above; marginal process of gonopod, when evident, not extending beyond apex. *Pseudothelphusa* 2
2. Tip of gonopod not folded, apical spines pointing apically; gonopod simple in structure. ..... *Pseudothelphusa (Achlidon) agrestis*
   Tip of gonopod folded; at least some of the apical spines pointing cephalad 3
3. Patch of well-defined, short, sub-apical spines on cephalic surface of gonopods, in addition to apical spines. ..... *Pseudothelphusa (Allacanthus) pittieri*
   Apical spines only 4
4. Large mesial tooth near apex of gonopod; shaft without broad lateral process. Subgenus *Megathelphusa* 5
   Apical part of gonopod broad, joined to rest of gonopod by narrow peduncle; usually with broad lateral processes. Subgenus *Ptychophallus* 6
5. Marginal process of gonopod curving laterad, ending at tip of gonopod. ..... *Pseudothelphusa magna*
   Marginal process curving mesiad, ending just short of tip of gonopod. ..... *Pseudothelphusa richmondi*
6. Lateral subapical process of gonopod not broad, not exceeding apical process; mesial process subapical. ..... *Pseudothelphusa xantusi*
   Lateral subapical process broad, exceeding apical process 7
7. Mesial apical process of gonopod broad, hatchet-shaped. ..... *Pseudothelphusa tristani*
   Mesial apical process narrow, finger-like 8

8. Lateral subapical process of gonopod not bilobed. ..... *Pseudothelphusa exilipes*
   Lateral subapical process bilobed 9
9. Mesial apical process of gonopod, seen in marginal view, nearly as long as lateral apical process; proximal lobe of subapical process sub-acute. Small species. ..... *Pseudothelphusa montana*
   Mesial subapical process much shorter than lateral process; proximal lobe of subapical process broadly rounded. Large species. ..... *Pseudothelphusa tumimanus*

IV. Systematic Account

Most of the specimens on which this account is based were collected by me in Costa Rica during the summer of 1962, and were identified by comparison with types in the U. S. National Museum. Specimens from the U. S. National Museum are indicated by the initials USNM. The drawings of *Epilobocera cubensis* are from a specimen borrowed from the Museum of Comparative Anatomy, Harvard University. All other specimens are at Tulane University.

Measurements, where given, are for greatest carapace width and median carapace length in millimeters, of the largest male examined. Immature males too small to be identified with certainty are simply included with the large males in the same collection and listed as "imm.". Some question of identity applies to any female *Pseudothelphusa*, and they also are grouped with the identified males. Specimens so small that the pleopods are not developed are designated "imm.". A number of collections did not include any identifiable specimens and are omitted. Figures in parentheses indicate the altitude in meters. Localities are in Costa Rica unless otherwise specified.

Synonymies are given only if the species has been mentioned by anyone other than Rathbun (1896, 1898, 1905), and Young (1900).

Pseudothelphusa tuberculata Rathbun is omitted from this account. There is a female from Boruca, in the U. S. National Museum, determined by Rathbun, but I believe that this is an erroneous identification, and that the range of *P. tuberculata* should be restricted to Guatemala. The same remarks apply to a female *Pseudothelphusa venezuelensis* Rathbun from La Palma.

In the illustrations of the gonopods, the caudal surface is always oriented so that the margin can be identified as a line extending the length of the gonopod, with a proximal tuft of setae. The cephalic surface is oriented so that at least some of the apical spines point directly toward the observer. In most Costa Rican species, the apical spines are directed cephalad, although this is not the case with many, if not most, Pseudothelphusidae. Most gonopods are more or less flattened caudocephalad, but the drawings of the caudal and cephalic surfaces are not necessarily at 180 degrees, so the gonopod may appear broader in one view than in the other. A standard orientation for gonopod drawings is desirable because figures of complex gonopods are difficult to compare if they are drawn from different sides. Best results are obtained if the right gonopod is removed from the crab for examination, and subsequently kept in a small cotton-stoppered vial in the jar with the crab.

The Subfamilies of the Pseudothelphusidae

Bott (1955) divided the old family Potamonidae into the three families Potamonidae, Pseudothelphusidae, and Deckiniidae, and his arrangement is adopted here, although with some reservations. All the American river crabs, except the genus *Trichodactylus* Latreille, 1825, belong in the family Pseudothelphusidae, which is restricted to the New World.

The relationships among the genera of the Pseudothelphusidae have undergone various treatments in the past as summarized by Colosi (1920). Gonopod morphology has not been used in previous classifications at the generic level, even though some carcinologists, notably Alcock (1910), Colosi (1920), and Bott (1955), have recognized the importance of the gonopods in distinguishing the Pseudothelphusidae from other river crabs. The Pseudothelphusidae can be divided into two readily distinguishable subfamilies on the basis of gonopod structure alone.

Pseudothelphusinae Ortmann, 1893

Pseudothelphusidae with gonopods armed at the tip with a group of apical spines, concentrated in a distinct area at the aperture of the sperm channel. Type genus, *Pseudo-*

thelphusa de Saussure, 1857. Other genera; *Potamocarcinus* H. Milne-Edwards, 1853; *Rathbunia* Nobili, 1896, and *Typhlopseudothelphusa* Rioja, 1952.

Epilobocerinae, new subfamily

Pseudothelphusidae with gonopods armed at the tip with both a patch of apical spines at the aperture of the sperm channel, and also with large, scattered spines. Type and only genus, *Epilobocera* Stimpson, 1860.

The difference between the gonopods of the two subfamilies can readily be seen by comparing *Epilobocera cubensis* Stimpson, 1860 (Figs. 16-17) with any *Pseudothelphusa.* Zimmer (1914) described a river crab from Columbia and placed it in *Epilobocera* on the basis of non-gonopodal structures. Fortunately, Zimmer provided good illustrations of the gonopod, which clearly show that *Epilobocera fuhrmanni* Zimmer should be *Pseudothelphusa fuhrmanni* (Zimmer).

Genus *Potamocarcinus* H. Milne-Edwards 1853

Potamocarcinus nicaraguensis Rathbun

Rathbun, 1893, p. 656; Colosi, 1920, p. 17; Smalley, 1964, p. 29.

Specimens examined: Trinidad, Heredia Prov., border between Costa Rica and Nicaragua; 1 May 1960; 2 ♀♀.—Resguardo, Guanacaste Prov., near Nicaraguan border; 7 Feb. 1960; 4 ♂♂.

Margin of gonopod straight; caudal process prominent, extending well beyond apex; a prominent mesial apical tooth; two smaller, spiniform, cephalic teeth placed close together; without lateral setae.

This species can be distinguished in the field from all other Costa Rican Pseudothelphusidae by the prominent spiniform anterolateral teeth of the carapace. If I had only the gonopod before me, I would place this species in *Pseudothelphusa (Megathelphusa).* A large species, found in lakes, rivers, and streams in Nicaragua and Costa Rica. Largest female examined by Rathbun, 95 x 60.1; largest Tulane male, 75.1 x 45.1.

Genus *Pseudothelphusa* de Saussure, 1857

Rathbun made two subgeneric divisions of the large genus *Pseudothelphusa,* one based on gonopod structure (1898, p. 513), the other mostly on structure of the carapace, third maxillipeds, and chelae (1905, p. 27 ff.). The two arrangements result in different classifications, but neither was formally proposed, and there are at present no subgenera recognized for *Pseudothelphusa.* Rathbun's grouping according to gonopod structure is, in my opinion, the more satisfactory of the two. A number of changes must be made in Rathbun's gonopod groups, but for the Costa Rican *Pseudothelphusa,* only the following changes are necessary: (1) remove *P. pittieri* from Group 1, and erect for it a monotypic subgenus, (2) add *P. exilipes* to Group 2, and (3) remove *P. agrestis* from Group 6 and erect for it a monotypic subgenus.

The phylogeny, evolution, and zoogeography of *Pseudothelphusa* cannot profitably be studied without a subgeneric classification, for which the most satisfactory criteria are gonopod characters. Subgenera are therefore proposed for the Costa Rican *Pseudothelphusa.* Subgenera can similarly be erected for other species groups of *Pseudothelphusa,* but a large number of unresolved taxonomic problems prevent further extension of the classification at this time.

Achlidon, new subgenus

Gonopod simple in structure, curving mesiad, with expanded apex. Blunt, mesial subapical tooth the only process. Apical spines directed apically, apex without folds. Margin curving mesiad, emerging near cephalic surface. Type and only species, *P. agrestis. Achlidon* (masc.)—unornamented.

Pseudothelphusa (Achlidon) agrestis Rathbun, 1898

Specimens examined: La Flor, near Torito, Cartago Prov., 1 ♂, 1 ♀, the types (USNM).

Illustrated by Rathbun (1898, p. 515). The shape of the gonopod is quite different from the other species in Rathbun's Group 6.

Allacanthos, new subgenus

Gonopod and margin straight, apex folded, sperm channel emerging on cephalic surface. With a blunt, mesial, apical lobe, and a small, sharp, apically directed lateral lobe bearing sparse apical spines. Cephalic and lateral surfaces with well defined area of small regularly spaced spines; row of scattered spines on mesial surface of shaft. Type and only species, *P. pittieri. Allacanthos* (fem.)—other spines.

Pseudothelphusa (Allacanthos) pittieri
Rathbun, 1898
(Figs. 1-3)

Specimens examined: Agua Buena, Puntarenas Prov.; 2 ♂♂, 1 ♀, the types (USNM).

A small species (19.1 x 11.9), with the characters of the subgenus. A small tubercle at the base of the moveable finger of the chela is distinctive. Rathbun thought the gonopod of *P. pittieri* to be similar to those of a group of Mexican and West Indian species (Group 1), but in fact it is unique.

Megathelphusa, new subgenus

Gonopod with large mesial tooth, visible in both cephalic and caudal aspects, and two smaller cephalic teeth, varying in position and shape. Marginal process not extending beyond apex, sperm channel emerging from beneath fold of tip of gonopod. Apical spines small, facing partly apically, partly cephalad. Setae prominent, particularly mesial setae. Two tubercles at base of movable finger of chelae, forming long area which is light-colored in fresh specimens. Type-species, *Pseudothelphusa magna;* other species, *P. richmondi. Megathelphusa* (fem.) —large river crab.

Rathbun separated *P. richmondi* and *P. magna* by the characters of the chelae, stating that the tubercle at the base of the fingers is lacking in *P. richmondi,* but in fact the two species have very similar chelae. Both species of *Megathelphusa* are widely distributed, in contrast to most Costa Rican Pseudothelphusidae.

Pseudothelphusa (Megathelphusa) magna
Rathbun, 1896

Holthuis, 1954, p. 33; Bott, 1956, p. 230; Smalley, 1964, p. 29.

Specimens examined: 11.5 mi. NNW Liberia, Guanacaste Prov.; 9 Feb. 1960; 1 ♂, 1 ♀.—Rio Virilla, 2 mi. W San José, San José Prov.; 11 Feb. 1960; 1 ♂.—Same locality; 24 Jan. 1961; 2 ♂♂, 1 ♀, 1 imm. ♂. —Rio Irigaray, on Pan Am Highway, Guanacaste Prov.; 21 Jan. 1961; 1 ♀.—Rio Las Vueltas, E of Nicaraguan border, Guanacaste Prov.; 21 Jan. 1961; 1 ♂, 1 ♀, 1 imm. ♂.— Small stream, E bank Rio Grande de Tárcoles, 3 mi. E Atenas, Alajuela Prov. (580 m); 11 July 1962; 3 ♂♂, 3 ♀♀, 1 imm.— Small stream, 0.3 mi. S above locality; 11 July 1962; 3 ♂♂, 1 ♀, 3 imm. ♂♂.—Rio Ciruelas, 0.2 mi. S RR crossing at Ciruelas, Alajuela Prov. (800 m); 20 July 1962; 4 ♂♂, 4 ♀♀, 2 imm.

Two cephalic teeth not separate, consisting of two teeth of single medially directed process. Gonopods similar to illustrations by Holthuis and Bott; some variation shown by mesial apical process.

P. magna is one of the largest species of Pseudothelphusidae, although no one has reported another specimen of the heroic size of one of Rathbun's syntypes (135 x 84); the largest Tulane male is 86.5 x 52.3. The specimens from Ciruelas were under large rocks in a nearly dry gully, and were found in pairs, probably copulating. Known from Costa Rica to Guatemala.

Pseudothelphusa (Megathelphusa) richmondi
Rathbun, 1893
(Figs. 4-6)

Nobili, 1897, p. 3 (but the same specimens listed by Colosi, 1920, p. 20, as *P.* sp.); Boone, 1929, p. 567.

Specimens examined: Tributary of Rio Escondido, 50 mi. from Bluefields, Nicaragua (probably near the town of Rama); 1 ♂, the holotype (USNM).—1.1 mi. N Turrialba, Cartago Prov. (600 m); 18 July 1962; 9 ♂♂, 15 ♀♀, 3 imm. ♂♂.

Cephalic teeth uneven in size, proximal twice size of distal, more pointed. Setae prominent, particularly mesial setae. Row of short setae on cephalic surface just below apical spines. Smaller than *P. magna;* holotype, 49 x 32.5; largest Tulane male, 62.7 x 40.6.

The Costa Rican specimens were found in a coffee plantation on a wet hillside. Ditches had been dug to drain seepage from the field, and the crabs were burrowing into the sides of the ditches. *P. richmondi* is known from Nicaragua to Panama.

Ptychophallus, new subgenus

Gonopod with expanded tip connected to shaft by narrow peduncle. Lateral process of apical expansion larger than mesial, bearing apical spines; mesial process either narrow and fingerlike, or broad and hatchet-shaped. Most species with very broad subapical lateral process, usually bilobed. Apical spines directed cephalad. Marginal process folded cephalad, not projecting beyond apex. Without marginal setae; lateral setae usually short, scattered; marginal and caudal setae present.

Type-species, *Pseudothelphusa tristani.* Other species: *P. montana, P. tumimanus, P. exilipes,* and *P. xantusi. Ptychophallus* (masc.)—folded gonopod. *P. tristani* is chosen as the type because it is common, easily recognized, and fairly typical. *Pseudothelphusa colombiana* Rathbun, 1893, from Panama and Mexico, should be placed in this subgenus on the authority of Rathbun (1893). Through an oversight, I did not examine the specimens in the U. S. National Museum on which Rathbun's description was based. The only other record of this subgenus outside of Costa Rica is an erroneous one for *P. xantusi* from La Guayra, Venezuela.

Pseudothelphusa (Ptychophallus) tristani
Rathbun, 1896
(Figs. 7-8)

Specimens examined: La Mina, Rio Torres, San José Prov.; 1 ♂, the holotype (USNM).—1 mi. NW Tabarcia, San José Prov.; 20 June 1962; 2 ♂♂, 5 ♀♀, 3 imm. ♂♂.—same locality; 17 July 1962; 9 ♂♂, 9 ♀♀, 1 imm. ♂, 3 imm.—2 mi. S. Villa Colon, San José Prov.; 29 June 1962; 2 ♂♂, 7♀♀.—same locality; 4 July 1962; 1 ♂, 3 ♀♀, 6 imm. ♂♂.—3 mi. E. Atenas, Alajuela Prov. (580 m); 7 July 1962, 4 ♂♂, 5 ♀♀, 1 imm.—0.5 mi. S Cebadilla, Alejuela Prov.; 11 July 1962; 6 ♂♂, 9 ♀♀ (1 ovigerous), 6 imm. ♂♂, 2 imm.—2.7 mi. S El Roble, Heredia Prov. (1200 m); 13 July 1962; 2 ♂♂, 1 ♀.—2.5 mi. NE Santiago Puriscal, San José Prov., 17 July 1962, 26 ♂♂, 16 ♀♀, 4 imm. ♂♂.—0.8 mi. W Piedades, San José Prov.; 26 July 1962; 12 ♂♂, 26 ♂♂, (4 with small crabs on abdomen), 6 imm. ♂♂.

Only *Ptychophallus* with mesial apical lobe broad and hatchet-shaped. Proximal process of subapical lobe small, setae sparse. Fingers of larger chelae gaping in largest males, closed tightly in smaller males.

Abundant in the hills and mountains south of San José. *P. tristani* is more terrestrial than *P. tumimanus* or *P. montana.* Typically, *P. tristani* is found under rocks or logs at the edge of streams, or even some distance from the stream edge. A cavity under the rock or log, filled with water, forms part of the crab's burrow.

Pseudothelphusa (Ptychophallus) montana
Rathbun, 1898
(Figs. 9-10)

P. convexa, Rathbun, 1898.

Specimens examined: Alto La Palma, San José Prov.; 2 ♂♂, 2 ♀♀, the types (USNM).—Palmar, Puntarenas Prov., 1 ♂, holotype of *P. convexa* (USNM).—0.6 mi. S. Alto La Palma, San José Prov.; 9 July 1962; 2 ♂♂, 2 ♀♀, 0.2 mi. S Alto La Palma; 9 July 1962; 2 ♂♂, 3 ♀♀, 2 imm. ♂♂.—Rio Honduras, 3.0 mi. N continental divide, San José Prov.; 9 July 1962; 9 ♂♂.—11 mi. NE Turrialba, Cartago Prov. (770 m); 6 July 1962; 4 ♂♂, 5 ♀♀, 6 imm. ♂♂.—same locality; 21 July 1962; 13 ♂♂, 14 ♀♀, 17 imm. ♂♂.—4 mi. E La Suiza, Cartago Prov.; 18 July 1962; 1 ♂, 2 ♀♀, 1 imm. ♂.

Similar to *P. tumimanus* and *P. exilipes.* Medial process of gonopod long, slender. Subapical lateral process bilobed, proximal lobe acutely angled, caudal surface with distinct depression between lobes. Small species (30.9 x 18.1).

Rathbun (1898) gave a confusing account of *P. montana* and *P. convexa.* The only distinct difference between the types is that the two subapical lateral lobes of *P. montana* are not so distinct, the more proximal lobe not so acute, and the depression between the two lobes on the caudal surface more shallow. However, her figures (1898, p. 516 and p. 526) show the opposite, that is *P. montana* with a deep depression on the caudal surface. Since the gonopods of the material examined by me vary in the shape of the subapical lateral lobes and degree of concavity of the caudal surface, *P. convexa* should be considered a synonym of *P. montana.* The name *P. montana* is chosen in preference to *P. convexa* because the specimens studied and illustrated in this work are from the type locality of *P. montana* and from the surrounding region.

The lack of females from Rio Honduras is due to the mixture of *P. tumimanus* and *P. montana* in the collection, and the difficulty of distinguishing the females. All the females were arbitrarily assigned to the more common *P. tumimanus.*

Found in streams, and under boards at an abandoned sawmill (northeast of Turrialba).

Pseudothelphusa (Ptychophallus) tumimanus
Rathbun, 1898
(Figs. 11-12)

Specimens examined: Cachí, Cartago Prov., 1 ♂, the holotype (USNM).—2 mi. S Cariblanco, Heredia Prov. (1200 m); 25 June 1962; 3 ♂♂, 7 ♀♀, 1 imm.—same locality, 28 June 1962, 4 ♂♂, 5 ♀♀ (2 with juveniles on abdomen), 2 imm. ♂♂.—same locality; 14 July 1962; 10 ♂♂, 5 ♀♀.—Rio Honduras, 3.0 mi. N continental divide, San José Prov.; 9 July 1962; 16♂♂, 31 ♀♀, 16 imm. ♂♂, 5 imm.—1.2 mi. SE El Roble, Heredia Prov. (1300 m); 13 July 1962; 1 ♂, 1 imm. ♂.

Lateral subapical process relatively larger than in other species of subgenus, tapering more gradually proximally, with scalloped border, and with short, heavy setae scattered along proximal part of lateral process.

A large species for the subgenus (Tulane, 60.3 x 35.7; holotype, after Rathbun, 70.2 x 42.2). Most specimens, and all the larger ones, were found in streams under rocks, or moving freely on the bottom.

Both Temnocephala and Branchiobdellidae were found on *P. tumimanus*, but they were mutually exclusive; the Temnocephala occurred on the population near Cariblanco, and the Branchiobdellidae on the crabs from Rio Honduras. The two populations are separated by about 18 miles of very rugged mountains. Hobbs and Villalobos (1958) report both groups of commensals occurring together on *Pseudothelphusa lamellifrons* Rathbun, 1893.

Pseudothelphusa (Ptychophallus) exilipes
Rathbun, 1898
(Figs. 13-14)

Specimens examined: Santa María de Dota, San José Prov.; 2 ♂♂, 4 ♀♀ (USNM).

Mesial apical lobe of gonopod downturned, more proximal than in *P. montana;* rounded distal lobe formed from margin at apex. Marginal and caudal setae prominent, individual setae long; long, scattered setae on lateral surface proximal to widest part of subapical lobe. Apical spines restricted to distal part of "patch".

The holotype of *P. exilipes* is a female from El Coronel. The present description and illustrations are based on a male from Santa María de Dota, about 51 kilometers from El Coronel, and identified with the type by Rathbun. Males from the type-locality would be very valuable. Collecting six miles from El Coronel yielded specimens only of *P. tumimanus* and *P. montana.* Similar problems of confirming the identity of female types are common in the Pseudothelphusidae.

Pseudothelphusa (Ptychophallus) xantusi
Rathbun, 1893
(Fig. 15)

Nobili, 1897, p. 3; Colosi, 1920, p. 19 (in the synonymy of *P. fossor*).

Specimens examined: Boruca, Puntarenas Prov.; 3 ♂♂, 1 imm. (USNM).

Without mesial apical lobe, the lobe placed subapically instead. Lateral subapical lobes poorly developed.

Although *P. xantusi* is a rather aberrant member of the subgenus, the folded tip bears the apical spines exactly as in other species of *Ptychophallus,* and the lateral subapical lobes are typical in their shape and position, although not nearly as broad as in the other species.

The holotype of *P. xantusi* is a female, locality unknown, but probably from Mexico, and almost certainly not from Costa Rica. In my opinion this species will eventually have to be declared a *species dubia* and a new name assigned to the distinctive species from Boruca. However, judgment should be deferred until the river crabs of Mexico are much better known.

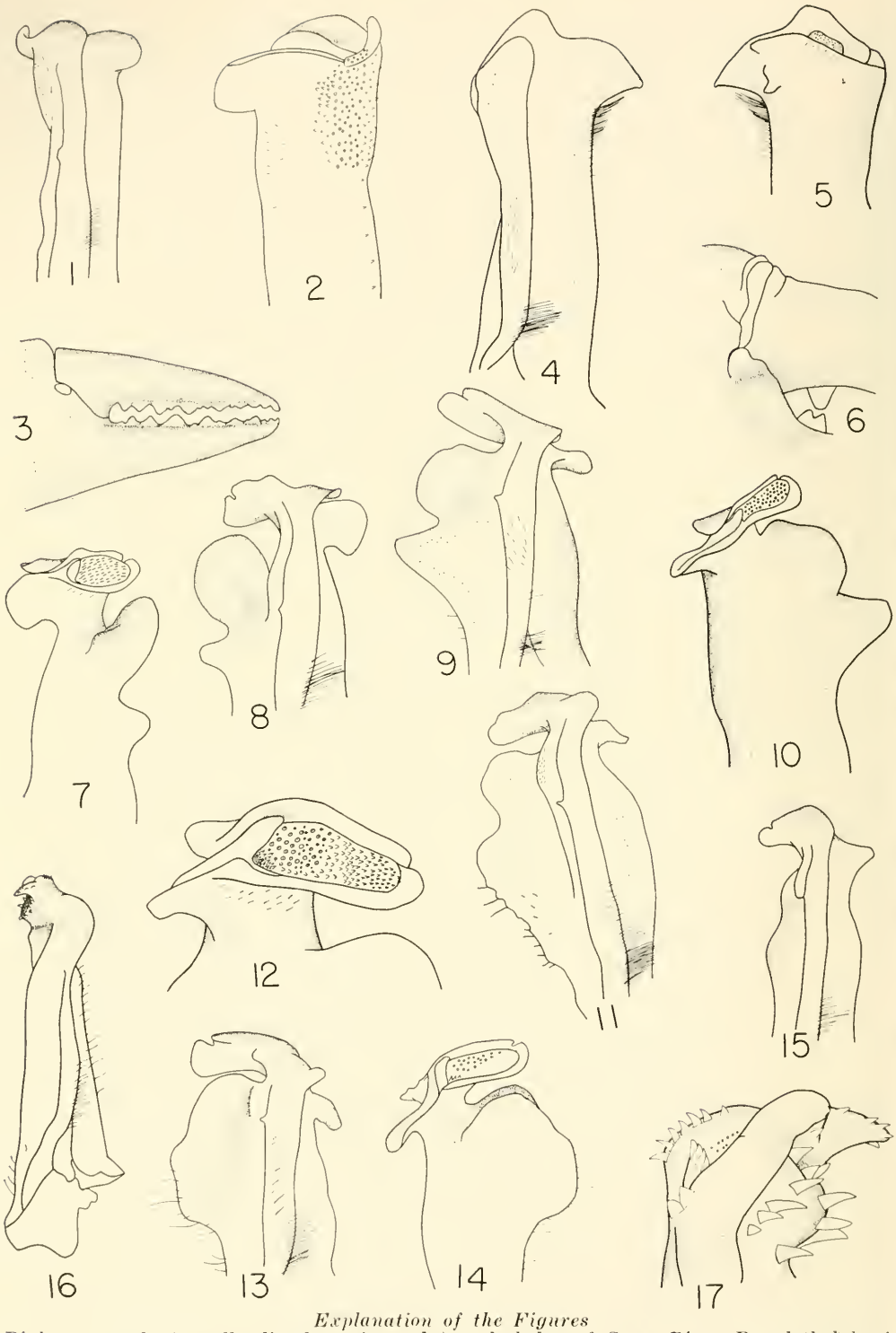
Acknowledgements

For help in the field, I am indebted to Dr. John DeAbate, Sr. Don Salvador Jiménez-Canossa, Dr. R. D. Suttkus, and especially my wife. Drs. Herbert W. Levi, F. A. Chace, Jr., and Raymond B. Manning were most helpful in loaning specimens; Dr. Manning was the subject of the greater part of these requests, with which he was most patient. This research was supported by a grant from the Systematics Section of the National Science Foundation (NSF-G20862), whose aid is gratefully acknowledged.

V. References Cited

Alcock, A. 1910. On the classification of the Potamonidae (Thelphusidae). *Rec. Indian Mus.* 5: 253-261.

Boone, L. 1929. A collection of brachyuran Crustacea from the Bay of Panama and



Explanation of the Figures

Right gonopods (usually distal portion only) and chelae of Costa Rican Pseudothelphusidae. 1-3, *Pseudothelphusa pittieri;* 4-6, *P. richmondi;* 7-8, *P. tristani;* 9-10, *P. montana;* 11-12, *P. tumimanus;* 13-14, *P. exilipes;* 15, *P. xantusi;* 16-17, *Epilobocera cubensis.* Drawn to different scales.

the fresh waters of the Canal Zone. *Bull. Amer. Mus. Nat. Hist.* 58: 561-583.

Bott, R. 1955. Die Süsswasserkrabben von Afrika (Crust. Decap.) und ihre Stammesgeschichte. *Ann. Mus. Roy. Congo Belge, C--Zool., Ser.* III, III, Vol. I(3): 209-352, pl. 1-30.

———. 1956. Dekapoden (Crustacea) aus El Salvador. 3. Süsswasserkrabben *(Pseudotelphusa). Senck. Biol.* 37: 229-242.

Colosi, G. 1920. I Potamonidi del R. Museo Zoologica di Torina. *Boll. Mus. Zool. Anat. Comp. R. Univ. Torino* 35(734): 1-39.

Milne-Edwards, H. 1853. Observations sur les affinités zoologiques et la classification naturelle des Crustacés. *Ann. Sci. Nat., Zool.* 18(3): 109-162.

Hobbs, Horton H., and Alejandro Villalobos F. 1958. The exoskeleton of a freshwater crab as a microhabitat for several invertebrates. *Virginia J. Sci. (N.S.)* 9: 395-396.

Holthuis, L. B. 1954. On a collection of decapod crustacea from the Republic of El Salvador (Central America). *Zool. Verhandel., Leiden, No.* 23: 1-43.

Latreille, P. A. 1825. *Familles naturelles du Règne animal.* Paris.

Nobili, G. 1896. Di un nuovo genere di Crostacei decapodi raccolto nel Darien dal dott. E. Festa. *Boll. Bus. Zool. Anat. Comp. R. Univ. Torino* 11(238): 1-2.

———. 1897. Viaggio del Dr. Enrico Festa nella Repubblica dell' Ecuador e regioni vicine. I decapodi terrestri e d'acqua dolce. *Boll. Mus. Zool. Anat. Comp. R. Univ. Torino* 12(275): 1-6.

Ortmann, A. E. 1893. Die Decapoden-Krebse des Strassburger Museums, mit besonderer Berucksichtigung der nov Herrn Dr. Döderlein bei Japan und den Liu-Kiu-Inseln gesammelten und zur Zeit im Strassburger Museum aufbewahrten Formen. VII. *Theil. Zool. Jahrb., Syst.* 7: 411-495.

Rathbun, M. 1893. Descriptions of new species of American fresh-water crabs. *Proc. U. S. Nat. Mus.*, 16: 649-661.

———. 1896. Descriptions of two new species of fresh-water crabs from Costa Rica. *Proc. U. S. Nat. Mus.* 18: 377-379.

———. 1898. A contribution to the knowledge of the fresh-water crabs of America—The Pseudothelphusinae. *Proc. U. S. Nat. Mus.* 21: 507-537.

———. 1905. Les crabes d'eau douce (Potamonidae). *Nouv. Arch. Mus. Hist. Nat. Paris,* ser. 4, 7: 159-321.

Rioja, E. 1952. Estudios carcinológicos. XXVIII. Descripción de un nuevo género de potamonidos cavernícolos y ciegos de la Cueva del Tio Ticho, Comitán, Chis. *An. Inst. Biol., Mexico* 23(1-2): 217-225.

Saussure, H. de. 1857. Diagnoses de quelques Crustacés nouveaux des Antilles et du Mexique. *Rev. Mag. Zool.* 9(2):304-306.

Selander, R. and P. Vaurie. 1962. A gazetteer to accompany the "Insecta" volumes of the "Biologia Centrali-Americana". *Amer. Mus. Novitates, No.* 20999: 1-70.

Smalley, A. 1964. A terminology for the gonopods of the American river crabs. *Syst. Zool.* 13:28-31.

Stimpson, W. 1860. Notes on North American Crustacea, No. 11. *Ann. Lyc. Nat Hist. N. Y.* 7: 176-246.

Young, C. 1900. *The stalk-eyed Crustacea of British Guiana, West Indies and Bermuda.* Watkins, London.

Zimmer, C. 1914. Beitrag zur Kentniss der Süsswasserdekapoden Kolumbiens. *Mem. Neuchâteloise des Sciences Naturelles* 5: 1-8.

August 21, 1964

MYSIDOPSIS ALMYRA, A NEW ESTUARINE MYSID CRUSTACEAN FROM LOUISIANA AND FLORIDA

THOMAS E. BOWMAN,
Division of Marine Invertebrates,
Smithsonian Institution,
Washington, D. C. 20560

ABSTRACT

Mysidopsis **almyra** is described from Lake Pontchartrain, Louisiana, St. Andrews Bay, Florida, and Buttonwood Canal, Florida.

Two species of *Mysidopsis* are known from the Atlantic and Gulf of Mexico coasts of the United States. *M. bigelowi* W. Tattersall (1926) occurs from New England to Louisiana, while *M. furca Bowman* (1957) is known only from the type-locality, off South Carolina. A third species, collected from brackish waters in Florida and Louisiana, is described below.

Mysidopsis **almyra**,[1] new species

Figures 1-24

Mysidopsis sp., Darnell, 1961, pp. 555-556.

Description. Length, from anterior margin of rostrum to end of telson, varies seasonally: 8.1-9.4 mm in 6 adults collected 19 Feb. 1954, 4.2-5.3 mm in 5 adults collected 30 July 1953 in Lake Pontchartrain, Louisiana. Anterior margin of carapace broadly round-triangular, not produced between eyes as rostrum; anterolateral angles rounded; posterior margin evenly concave, thoracic somite 8 and a small portion of thoracic somite 7 exposed in dorsal view. Eye large, cornea kidney-shaped, without ocular papilla. Telson slightly shorter than pleonite 6, linguiform, with broadly rounded apex; lateral margins each with about 20 spines along entire length; apex with 6-7 pairs of closely set long strong spines, central pair longest, about 1/4 as long as telson. First segment of peduncle of antenna 1 longer than third, with rounded lobe bearing long recurved setae arising from inner distal angle; male lobe slender, about as long as first segment, inner margin thickly set with setae. Scale of antenna 2 narrowly lanceolate, 2-segmented, distal segment about 0.4 as long as proximal; distal segment of peduncle produced into spine on outer distal corner. Labrum rounded anteriorly; posterior margin with small central margination; middle 2/3 armed with short setae. Molar of mandible obsolete; incisor curved so that in some views it appears bipartite, with 9 teeth in left mandible, 5 teeth in right; left lacinia mobilis broad, with 6 teeth; right lacinia much smaller, constricted at base, with 5 teeth; spine row of 7-8 spines, with numerous setae interspersed among spines; palp well developed. Outer plate of maxilla 1 with 9 spines at apex; inner plate with 2 setae at apex and 1 on outer margin. Proximal lobe (lobe of second segment) of maxilla 2 with 4 setae on truncate apex; exopod with 4 setae. Thoracic leg 1 (maxilliped) short and stout. Leg 2 (endopod of 2nd thoracic appendage) slender; segment 6 slightly longer than segment 5; segment 7 ending in nail, posterior margin with 4 robust long barbed setae, anterior margin with about 10 long naked setae. Legs 3-7 slender, subequal; tarsus of 2 segments, first about 4 times as long as second; prehensile distal end formed by long slender dactyl and 5 long setae, 4 inserted at distal end of first and 1 at distal end of second tarsal segment.

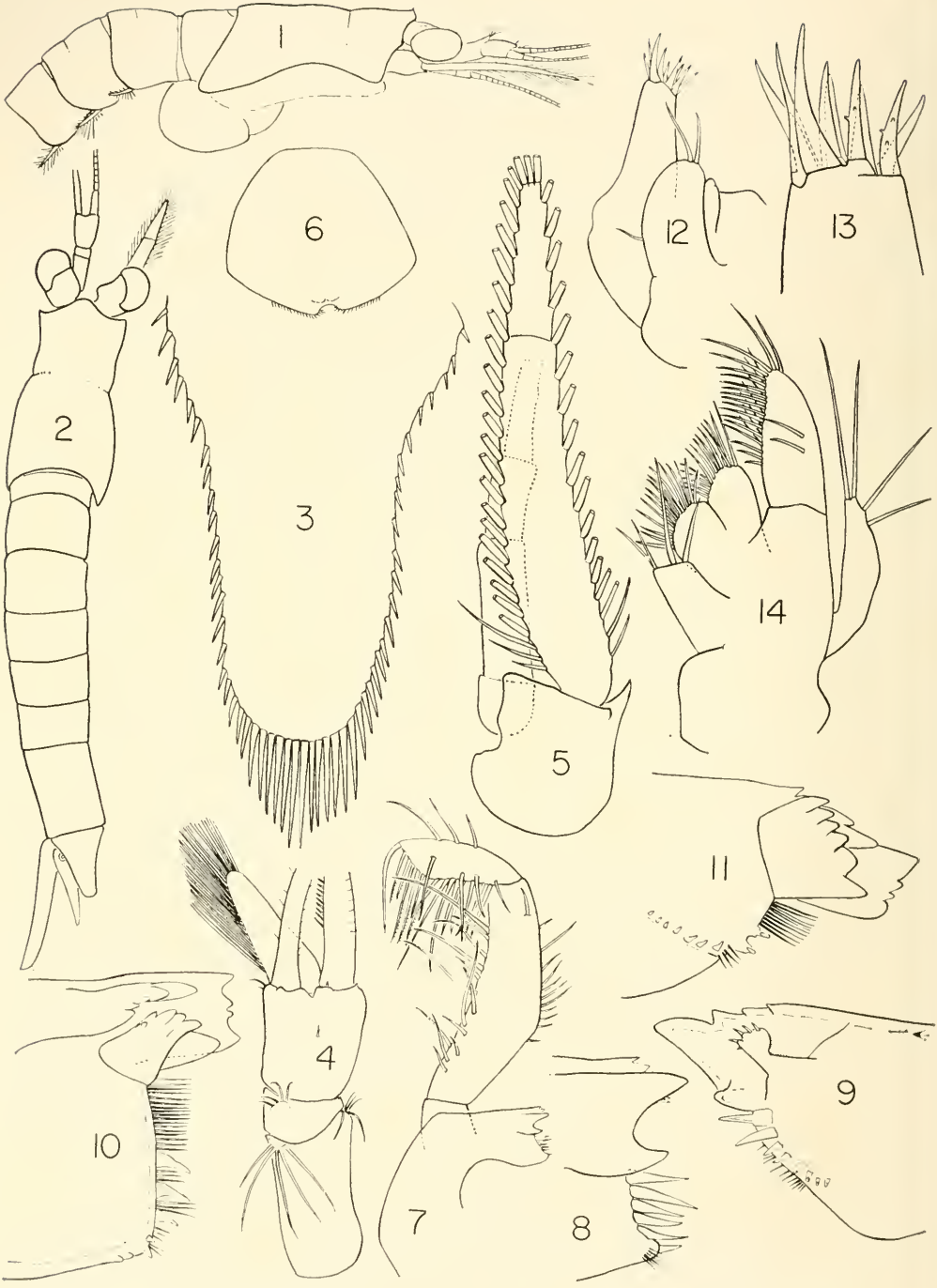
[1] From the Greek ἀλμυρός, brackish.

EDITORIAL COMMITTEE FOR THIS PAPER:

DR. WILLIAM D. CLARKE, Marine Sciences Section, General Motors Defense Research Laboratories, Goleta, California

SIDNEY S. HERMAN, Assistant Professor of Biology, Lehigh University, Bethlehem, Pennsylvania

DR. OLIVE S. TATTERSALL, Pendeen, 66, Sinah Lane, Hayling Island, Hants, England



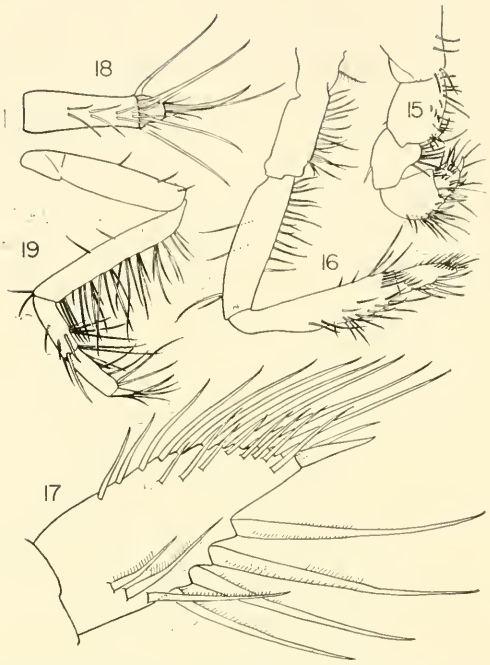
Figures 1-14. Mysidopsis almyra, new species: 1. anterior part of female, lateral; 2. male, dorsal; 3. telson, dorsal; 4. male antenna 1, proximal segments, dorsal; 5. scale of female antenna 2, dorsal; 6. labrum; 7. right mandible, external (ventral) view; 8. right mandible, gnathobasic process, external view; 9. same, internal (dorsal) view; 10. left mandible, gnathobasic process, internal view; 11. same, oblique internal view; 12. maxilla 1; 13. maxilla 1, outer plate; 14. maxilla 2.

Leg 8 much shorter than other legs. Male pleopod 1 with lobe bearing 6 setae at base of endopod. Endopod of male pleopod 4 with 2 lobes bearing 1 and 6 setae respectively; exopod longer than endopod, with long barbed robust apical spine. Exopod of uropod about twice as long as telson (excluding terminal spines), curved gently outward; endopod about 3/4 as long as exopod, armed on ventral surface near medial margin distal to statocyst with a single long spine.

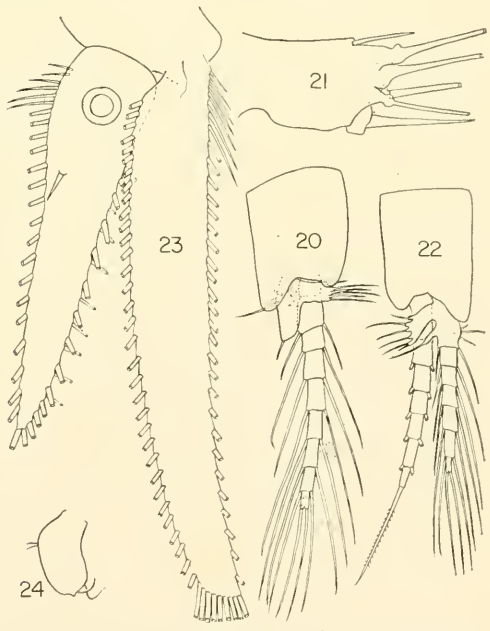
Color. In preserved specimens black chromatophores are distributed as follows: Dorsally, 1 pair at base of telson; ventrally 2 pairs on thorax, 1 in midline near posterior margin of pleonites 1-5, 1 on each posterior oostegite near base.

Types. Male holotype, USNM 110924, female allotype, USNM 110925, and 8 paratypes, from station A. I. 188, 2.4 km offshore from the mouth of Bayou St. John, Lake Pontchartrain, Louisiana, collected 28 Dec. 1953, by Rezneat M. Darnell. More than 450 specimens collected by Dr. Darnell from other stations in Lake Pontchartrain in 1953-54 have also been designated as paratypes.

Occurrence. In addition to the specimens from Lake Pontchartrain, I have identified specimens of *M. almyra* from St. Andrews Bay, Florida, collected by Thomas L. Hopkins, and from the north end of Buttonwood Canal, connecting Florida Bay at Flamingo with Coot Bay, in the Cape Sable region of southern Florida, collected by Raymond B. Manning (*cf.* Tabb and Manning, 1961; Tabb, Dubrow, and Manning, 1962). At all 3 localities the salinity is low, at least seasonally. At the Lake Pontchartrain stations from which I have specimens of *M. almyra,* the salinity varied from 2.0-5.2‰, and Darnell (1958) reports a salinity during his study (July 1953 to August 1954), of 1.2-18.6‰, with an average of less than 6‰ and a maximum of less than 9‰ for most months. In the St. Andrews Bay system the salinity ranges from low values in the upper reaches to values only slightly below full ocean salinity in St. Andrews Bay proper, West Pass, and East Pass (Jones and Ichiye, 1960; Ichiye and Jones, 1961). Specimens of *Mysidopsis almyra* were collected by Hopkins at stations S3 and S5 (Hopkins, 1963) in St. Andrew Bay and West Pass respectively, and the salinities at the times of collection were 33.1‰ and



Figures 15-19. Mysidopsis almyra, new species: 15. leg 1; 16. leg 2; 17. leg 2, distal segment; 18. leg 3, distal segments, viewed from above; 19. leg 8.



Figures 20-24. Mysidopsis almyra, new species: 20. pleopod 1, male; 21. pleopod 1, male, endopodal lobe; 22. pleopod 4, male; 23. left uropod, ventral; 24. genital appendage, male.

27.3-33.7‰ respectively (Hopkins, in litt.). At the site of collection in Buttonwood Canal the salinity undergoes marked fluctuations, varying from less than 18‰ to more than 40‰ (Tabb, Dubrow, and Manning, 1959).

Mysidopsis almyra is very abundant in Lake Pontchartrain. Quoting Darnell (1961), the zooplankton "is dominated by the calanoid copepod *(Acartia tonsa)* and to a lesser extent by adult schizopods (*Mysidopsis* sp.) and larval penaeid shrimp." *M. almyra* is an important item in the diet of a number of Lake Pontchartrain fishes (Darnell, 1958). Both young and adult *Anchoa mitchilli diaphana* feed on this mysid; in other fishes *(Ictalurus furcatus, Cynoscion arenarius, C. nebulosus, Micropogon undulatus, Sciaenops ocellatus)* only the young specimens feed on *Mysidopsis,* the older individuals turning to larger prey. Finally, the young of some fishes *(Menidia beryllina* and *Bairdiella chrysura)* prey mostly on copepods; as these fishes grow older, they come to depend more on mysids.

Remarks. Only 3 species of *Mysidopsis, M. angusta* G. O. Sars, *M. didelphys* Norman, and *M. indica* W. Tattersall, have a single spine on the uropodal endopod near the statocyst. These species differ from *M. almyra* in having very short distal segments of the antennal scales and 3-segmented tarsi on thoracic legs 3-8, and their telsons are quite different. Only 1 species of *Mysidopsis, M. bigelowi* W. Tattersall, has been reported from the Gulf of Mexico: Tattersall (1951) reports it from Calcasieu Pass, Louisiana (I have examined these specimens and confirm his identification); Clarke (1956) records it from 10 miles off Barataria Light, Louisiana, and the U. S. National Museum has a single specimen collected by the M/V Silver Bay off southern Florida (26°20'N, 83°02'W). *M. bigelowi* is easily distinguished from *M. almyra* by its smaller eye, unsegmented antennal scale, the very robust thoracic leg 2, the presence of 5 spines near the statocyst, and the armature of the telson.

References Cited

Bowman, Thomas E. 1957. A new species of *Mysidopsis* (Crustacea: Mysidacea) from the southeastern coast of the United States. *Proc. U. S. Nat. Mus.* 107(3378): 1-7.

Clarke, William D. 1956. A further description of *Promysis atlantica* Tattersall (Crustacea, Mysidacea). American Mus. Novitates 1755: 1-5.

Darnell, Rezneat M. 1958. Food habits of fishes and larger invertebrates of Lake Pontchartrain, Louisiana, an estuarine community. *Publ. Inst. Mar. Sci. Univ. Texas* 5: 353-416.

———— 1961. Trophic spectrum of an estuarine community, based on studies of Lake Pontchartrain, Louisiana. *Ecology* 42(3): 553-568.

Hopkins, Thomas L. 1963. The variation in the catch of plankton nets in a system of estuaries. *J. Mar. Res.* 21(1): 39-47.

Ichiye, Takashi and Meredith L. Jones 1961. On the hydrography of the St. Andrew Bay System, Florida. *Limnol. Oceanogr.* 6(3): 302-311.

Jones, Meredith and Takashi Ichiye 1960. Hydrographic data of the St. Andrews Bay system, Florida. *Florida State Univ. Oceanogr. Inst. Contr.* 143: 1-56 (mimeographed).

Tabb, Durbin C., David C. Dubrow, and Raymond B. Manning 1959. Hydrographic data from the inshore bays and estuaries of Everglades National Park, Florida, 1957-1959. *Mar. Lab. Univ. Miami Rept.* 59-5: 1-26 (Mimeographed).

———— 1962. The ecology of northern Florida Bay and adjacent estuaries. *Florida State Board Conserv. Tech. Ser.* 39: 1-79.

Tabb, Durbin C. and Raymond B. Manning 1961. A checklist of the flora and fauna of northern Florida Bay and adjacent brackish waters of the Florida mainland collected during the period July, 1957 through September, 1960. *Bull. Mar. Sci. Gulf and Caribbean* 11(4): 552-649.

Tattersall, Walter M. 1926. Crustaceans of the orders Euphausiacea and Mysidacea from the western Atlantic. *Proc. U. S. Nat. Mus.* 69(2634): 1-28, pls. 1-2.

———— 1951. A review of the Mysidacea of the United States National Museum. *Bull. U. S. Nat. Mus.* 201: 1-292.

August 21, 1964

TULANE STUDIES IN ZOOLOGY

Volume 12, Number 2 February 23, 1965

Age Determination of the Cotton Rat *(Sigmodon hispidus)**

ROBERT K. CHIPMAN,

Department of Zoology,
University of Vermont,
Burlington, Vermont

CONTENTS

I. Abstract 19

II. Introduction 20

III. Material and Methods 21
A. Laboratory study 21
B. Field study 22

IV. Results 22
A. General body measurements 22
B. Pelage and molts 24
C. Reproduction 25
D. Teeth 27
E. Skeleton 28
F. Lens weight 31
G. Field study 32

V. Discussion and Conclusions 35

VI. Acknowledgements 37

VII. References Cited 37

I. Abstract

A study based on 316 known-age specimens of the cotton rat, *Sigmodon hispidus hispidus*, from southeastern Louisiana consisted of a laboratory and a field study. The categories of morphological characters examined were: body measurements; pelage and molting; reproductive activity; teeth; skeletal growth; and lens weight. The changes of these characters were studied through twelve months of age. The laboratory study showed that body length, molting stage, epiphyseal fusion, skull measurements, and dry lens weight combine to give a high degree of success for age-determination through six months of age.

The field study consisted of releasing 96 known-age cotton rats and successive periods of retrapping. The retrapping data support the conclusions of the laboratory study. Weight as an age-determining character is discussed and evaluated from the field data of this and other studies.

* This paper is based on a dissertation submitted in partial fulfillment of the requirements for the Ph.D. degree in Zoology at Tulane University, New Orleans, Louisiana, 1963.

Editorial Committee for this Paper:

Kyle R. Barbehenn, Lecturer on Biology, Department of Biology, University of Pennsylvania, Philadelphia, Pennsylvania

James N. Layne, Associate Professor of Zoology, Department of Conservation, Cornell University, Ithaca, New York

Norman C. Negus, Associate Professor of Zoology, Department of Zoology, Tulane University, New Orleans, Louisiana

II. Introduction

The need for reliable criteria for estimating the age of wild animals has been noted by many researchers and has been reviewed by Alexander (1958). Support for the study of age-indicating techniques has been devoted primarily to the larger game mammals due to sporting interests. Even when studies have been undertaken on smaller mammals, the emphasis is still placed on those species that are of interest either for hunting or for their commercial fur value. With the recent interest in the study of populations of small rodents and particularly the occasional dramatic fluctuations in their numbers, there is an increasing need for accurate methods for determining age classes.

The degree of accuracy necessary for estimating the age of any given animal will depend on the species itself. For example, if the species does not breed until it is several years old, the estimation of age in units of time of less than one year will have little practical value. If, however, the species breeds at the end of its first year, then estimation of age to one year or even less would be desirable to distinguish between young of the year and adults for the next breeding season. In the case of small rodents more precise estimation of age is necessary as many of the young will become reproductively active during the breeding season in which they were born. Three or more generations in a breeding season of a small rodent are not uncommon and may be the rule especially if the species breeds throughout the year. Occasional trapping in the animal's natural habitat will not solve the problem of age determination as the age of the captured animals so collected will be unknown, and only rough approximations of age classes can be formulated. A solution can only be found by first studying the development of various morphological characters on animals whose individual ages are known. Ideally, field studies should be undertaken concurrently on known-age animals to verify or adjust the laboratory derived data.

Thus, the purpose of this study was to determine useful age-determination characteristics from laboratory-raised cotton rats *(Sigmodon hispidus)* and to field-test the application of those techniques. Hopefully, the techniques that are successful for determining the age of the cotton rat will aid other researchers in age determination of small rodents.

Studies on growth of the cotton rat are limited largely to weight and measurement data. Svihla (1929) described cotton rats at birth, their early growth, and their ability to feed at about ten days of age. Meyer and Marsh (1943) noted that cotton rats become sexually mature at six to seven weeks. In the most elaborate study of growth of the cotton rat Meyer and Meyer (1944) presented considerable data on the growth of the young and additional data on growth through 15 months. Body weights are given in units of 50 days of age, but do not give good indication of being reliable criteria for aging of the animal. Furthermore, the sample size is limited to three to six animals. Information was presented that the rate of growth is influenced by the age of weaning. Data were also given for growth of various endocrine glands, but the areas of overlap from one age group to another were too extensive for estimating the age. No data were presented on body measurements, the growth of bones, the progression of molts, the development of the baculum, or the several other categories investigated in this study.

McIntire, Schweigert, and Elvehjem (1944) studied the increase in weight of the cotton rat to six weeks of age. The authors noted that both sexes grow at the same rate although the female is somewhat smaller than the male at any given age. Odum (1955) indicated breeding begins at a weight of 62-87 grams and at an age of 40-50 days. Individual size of the animals varied with the density of the population, animals being larger at lower than at higher densities. Data on weight were given for a limited number of known-age individuals. Odum also noted that very few individuals survived six months of live trapping, which may give some indication of longevity under field conditions.

Scalander and Walker (1955) suggested that size is no indication of reproductive capabilities. The population studied by these authors was aged by the use of the laboratory weight data of Meyer and Meyer (1944). Age classes based on body measurements were thought to be of little value as these classes had little relationship to weight. Keys (1958) followed the rate of embryonic and early postnatal development. He noted that

the cotton rat is quite precocious at birth and develops at a remarkably rapid rate. His study was not carried beyond 15 days of age.

III. Material and Methods

A. Laboratory Study

A breeding colony of wild cotton rats from southern Louisiana was organized in the spring and summer of 1960. Some of the young born of the wild cotton rats were also used as breeders in the laboratory. Breeding pairs were housed in large cages. Large fruit juice cans and cotton batting were found to make satisfactory nesting sites. Little fighting occurred after the first few days of pairing.

The females usually bore young two to four months after pairing. The male ignored the newborn young, and was left continually in the cage to take advantage of the post-partum estrus. The breeding females were palpated every two weeks to determine pregnancies. Once a litter was expected the cage was checked daily. At parturition the female would bar the male from the nest can; he then made a nest elsewhere in the cage. This action normally served to establish the date of birth. Also, as the eyes of the young are closed at birth but open the next day, a quick check of the newborn young would verify the date of birth.

The laboratory-born young that were used as breeders were usually paired when weaned (three weeks). At this age males and females were amicable. If pairing was delayed until after six weeks, some fighting resulted. In a few instances when the newborn young were a week to ten days old, the female, whether wild or laboratory raised, would viciously attack the male, chewing the hide from the back of the head to the sacral region. The pair was then separated and no further attempt was made to breed the female, although invariably a litter was born about two weeks after the separation.

The cotton rats were fed a diet of Wayne Lablox exclusively. Water was available *ad libitum*. The breeders were occasionally fed fresh greens in the earlier stages of this study. Most of the laboratory-bred cotton rats were secretive during the day, or at night when any activity was taking place in the laboratory. Although I made constant efforts to handle and tame the cotton rats, especially the young, the attempt proved useless. The tamest animals in the colony were wild-born, adult breeders. Generally the animals were removed from their cages by trapping them in their nest can or by chasing them into a Sherman live trap. The animals were then etherized for examination. Once subdued the animals would not bite but would still try to escape.

Meyer and Meyer (1944) showed that cotton rats weaned at 10 days of age did not gain weight as rapidly as those weaned at 20 or 30 days, the difference between the latter two ages being slight. Rabasa (1952) showed growth rates in albino rats to vary depending on the number of individuals per cage. For these reasons all cotton rats were weaned at the same age (21 days) and, with the exception of the few used for breeding purposes, were caged individually. Cages contained between 110 and 120 square inches of floor space and were supplied with coarse sawdust or shavings, a nest can of suitable size, and some cotton for nesting material. The nesting material was extensively used during winter, but was generally ignored during summer, although the temperature in the air-conditioned animal room was seldom lower than 65° F or higher than 75° F. I attempted to limit the photoperiod to that available as sunlight. Occasionally the animals received additional light when night work was necessary. The variations of light and temperature were kept to a minimum whenever possible, but may have affected some of the laboratory data, as will be discussed below.

The study was based on 12 samples. The first sample was made up of one-month-old animals. Successive samples were one month older than previous samples through 12 months of age. Each sample was derived from 3 to 5 separate litters and was planned to be composed of 5 males and 5 females. Cotton rats were assigned at the time of weaning to the older incomplete month-age samples. The first few litters were composed predominantly of males, causing the 12-month sample to have an undesirably high number of this sex. With the exception of the conditions described above, the animals were assigned to a sample at random. A few individuals died or were accidently killed prior to attaining their desired age, causing some deviation from this plan. Adjustments were made where possible.

Three wild-caught individuals were kept

TABLE 1.
Distribution of individuals forming the laboratory study.

	Age of Sample (Months)												
	1	2	3	4	5	6	7	8	9	10	11	12	18
Males	5	5	6	5	5	5	5	6	3	3	4	9	2
Females	6	5	6	5	4	5	8	1	7	6	5	2	1
Total	11	10	12	10	9	10	13	7	10	9	9	11	3
Number of litters represented	4	5	5	5	4	4	5	3	3	3	4	4	–

in captivity as breeders for 16 months. These were judged to be two or more months old at capture and are thus considered to have been 18 months or older when sacrificed. The data from these individuals were incorporated where possible. The composition of each month-age sample as to number, sexes, etc., is given in Table 1. The animals used in this study came from litters ranging from 5 to 10 young. No significant difference existed in weight or body measurements between the different sized litters.

All cotton rats were etherized and examined every two to four weeks for molting and reproductive condition. Individuals were sacrificed with ether when they had reached the desired age in months and on the same day of the month as their date of birth. The animal was then weighed, and the standard body measurements [total, tail, hind foot (not including nail), and ear (measured from the notch) lengths] were taken. The cotton rat was then skinned, the pelt being pinned out flat for drying. Both eyes were removed, placed in formalin, and the lenses later removed. The lenses were dried and weighed on a Mettler analytical balance to 0.1 mg.

The skull was severed, dried, and cleaned by dermestid beetles. The left forelimb and scapula were removed, fixed in 40% isopropyl alcohol, and later macerated and stained to study the epiphyseal areas. The right forelimb was similarly removed and preserved in formalin together with the tail. Both structures were later X-rayed for epiphyseal fusion. The entire penis was removed, macerated, and the baculum stained. Other reproductive structures were inspected, and pertinent notes taken. The remaining portion of the carcass was preserved in formalin.

B. Field Study

Growth data on laboratory-raised individuals of a wild species would not be expected to be the same as on animals in their natural habitat. Many differences exist between the laboratory and the natural habitat, such as food and climatic factors. Moreover, the cage environment may produce conditions that affect the normal growth of the animal. The limitations of activity, the lack of extreme environmental variation, and the change in social patterns are difficult to evaluate. Thus I attempted to obtain growth data on known-age cotton rats in their natural habitat by releasing and retrapping young cotton rats born in the laboratory (individually marked by toe-clip). The retrapped individuals were examined and released, hopefully to be retrapped a second time.

IV. RESULTS

A. General Body Measurements

The body length measurement was obtained by subtracting the tail length from the total length. I consider this computed measurement more reliable than either of the other two measurements, as portions of the tail are frequently lost.

The data for weight (Fig. 1) and for body

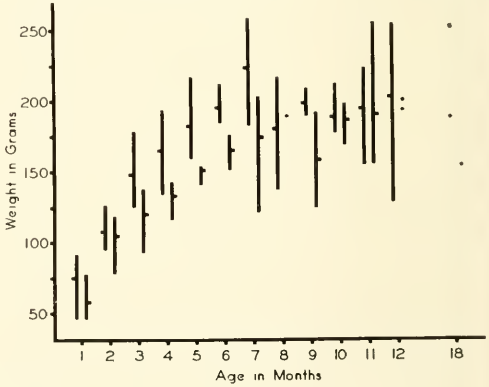


Figure 1. Body weight when sacrificed of known-age cotton rats by sex. The vertical line indicates the range and the horizontal line the mean of the sample. The left line of each pair is the data for males, the right line the data for females.

length (Fig. 2) are presented by sex. The difference between the sexes for these characters was considered significant ($P \leq 0.02$). The sexual dimorphism of hind foot and ear length (Fig. 3) is not considered significant ($P \geq 0.3$), and the data are combined for both sexes.

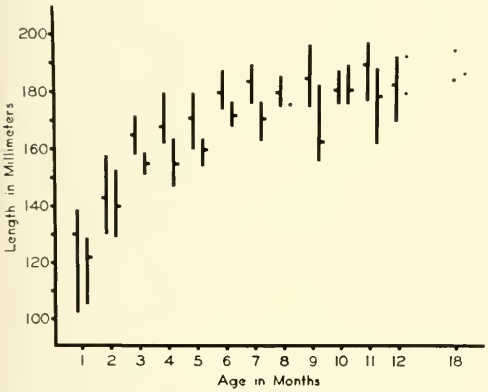


Figure 2. Body length when sacrificed of known-age cotton rats by sex. (See Figure 1 for description).

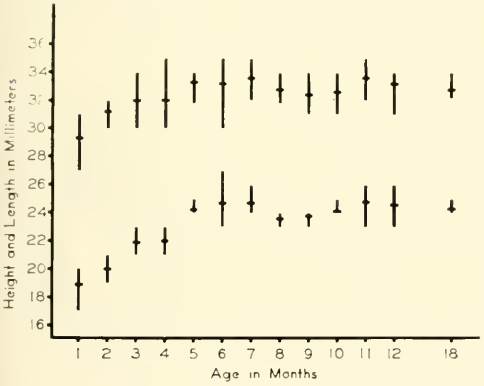


Figure 3. Ear height and hind foot length when sacrificed of known-age cotton rats. Data are for both sexes. Upper series of data are for hind foot length; lower series of data are for ear height. The vertical line represents the range and the horizontal line the mean of the sample.

While of limited value for age determination, these data should be considered in detail as these measurements are classical mammalian measurements. The measurements differentiate satisfactorily between one- and two-month-old animals, and distinguish these two age groups from older specimens. The age groups are best separated on the basis of body length and, to a lesser extent, by hind foot and ear lengths. Weight appears to be least related to age and is the most variable measurement.

The usefulness of any character for age determination depends in part on knowing and evaluating its variability. One possible variable might be the day length during the first few months of the cotton rat's life, since this was not controlled. The body length of nine males and five females born between September 8th and 12th are compared with 11 males and 12 females born between January 11th and 14th (Fig. 4). The first group

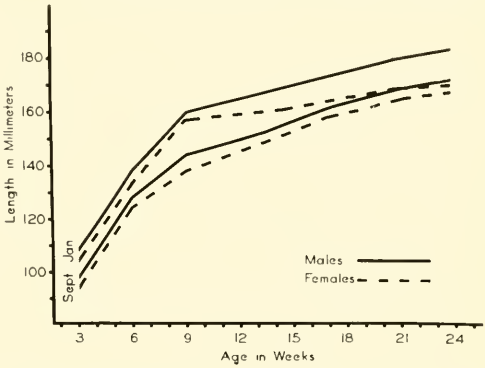


Figure 4. Variation in mean growth rates of known-age cotton rats, depending on the time of the year in which the animals were born.

was exposed therefore to a decreasing day length for three months and then to an increasing photoperiod, the second group being exposed only to an increasing day length. The January group was consistently larger at each age in body length than the September group. While Figure 4 shows only the means for the sample, the ranges of the measurement showed little overlap. At three weeks of age the means differ by 10 mm, while at nine weeks the differences are 14 mm for females and 19 mm for males. At these two points there are no areas of overlap of the range. For the males this difference in body length is maintained until twenty-three weeks of age, the limit of the data. For the females the means appear to be approaching each other at this age.

Body length is the most reliable measurement for age determination (Fig. 2). However, the seasonal variation, whatever its basis, could handicap the data. Perhaps separate growth curves could be used during different seasons, but this seems a questionable procedure.

A second source of variation might be

genetic, i.e., would growth curves determined by animals from one area be applicable to animals from another area? The only other study of laboratory cotton rats is that of Meyer and Meyer (1944). The stock for their colony came from Baton Rouge, Louisiana, 80 miles from the locality of my stock, and belong to the same subspecies *(S. h. hispidus)*. The only comparable data presented by these authors are body weights, and when their growth curves are plotted with mine the curves are virtually contiguous. This fact does not really answer the question posed as to genetic variability, although the similarity of the two growth curves suggests the data of my study might be used within the range of this subspecies safely.

A third question raised by the data is the apparent decrease in means and ranges of measurements at 8 or 9 months in Figures 1, 2, and 3. Each age sample comprises only the measurements of the sacrificed animals. Thus at 8 or 9 months there is no decrease but only the data from smaller animals. The reason for these smaller animals is not at all clear. The best suggestion seems to be the season in which the specific individuals were born. Those animals forming the eight- and nine-month samples were born in November and December, while those forming the younger age samples were born in January through March. Photoperiod can be suggested as the cause, but the mechanism is only conjecture.

Undoubtedly other factors will affect body weight and measurements. Sealander and Walker (1955) and Dunaway and Kaye (1964) have shown the mean body weights to decline during winter when depot body fat is being rapidly consumed and recruitment of the population is low.

B. *Pelage and Molts*

The results presented in this section are based primarily on observations of the dried pelt, with data of live animals being used as a check and/or elaboration.

The pelage of cotton rats displays a remarkable degree of uniformity throughout the animal's life. All the pelts were viewed at one time, but no real variations in color, shade, or texture could be observed except for very young cotton rats (one to two weeks old) in which the pelage was notably softer and composed of shorter hairs.

The actual molting patterns or progressions are diagramed in Figure 5. Several specific molts can be demonstrated ontogenetically. The newborn cotton rat is completely furred with short hairs somewhat darker than the adult. The juvenile pelage becomes complete within one week of age at which time the young cotton rat begins the very rapid molt to the subadult pelage. This molt begins in the ventral thoracic region. The three-week-old animal is molting laterally. At four weeks of age the animal is molting dorsally only. The new pelage is complete between five and six weeks of age, and the animal is now a subadult (i.e., may become reproductively active but physically smaller than the adult body size). This molt is extremely constant both in pattern and duration.

The next molt is termed the adult molt, since at its completion the cotton rat has reached adult size and the growth rate decreases abruptly. This molt usually begins at five to six weeks of age, often while the previously described molt is still present dorsally particularly on the top of the head. The progression of this adult molt is the same as for the subadult molt except for duration. The first molt requires about one month for completion while the adult molt requires two and one-half to three months. As a practical point, these two molts can be distinguished by: (1) the presence of juvenile pelage dorsally in the subadult molt; (2) the adult molt occurring as a narrow lateral band while the subadubt molt being present over one-half of the body surface at once; (3) the small size of the animal during the subadult molt.

As early as five months but usually around six months, the cotton rats molt again. This molt, very irregular both in duration and extent, has been termed a patch molt. My observations indicate that this molt follows the general pattern described for the previous molts and differs in that only small disconnected areas are molting at any one time. Both the duration and precise progression of this molt are difficult to follow, especially since the animal will frequently stop molting only to start again where it stopped or commence a new molt, or both.

Further adult molts occur with increasing irregularity both in area and duration. Molting is most easily observed when present laterally, particularly around the front limbs

and on the cheeks. The molting areas are small and scattered, and become even more so as the molt progresses dorsally. I have presumed the typical ventral-to-dorsal progression occurs, but definite observations are insufficient for a positive description due to the limited number of animals raised to the older age samples. The later adult molts appear strongly influenced by photoperiod and, in the case of a few known-age females used as breeders, by reproduction as well.

The adult molts need more critical study than could be undertaken. However, if a normal longevity of six to eight months is postulated, then the molting pattern, if closely examined, could be helpful for estimating the age of the cotton rat. If the specimen shows no molting, then the animal is either in complete subadult pelage (about six weeks old) or in complete adult pelage (about five months old). Body length or weight could be used to distinguish these two ages. The use of the molting pattern for age determination of cotton rats does not consider environmental variations.

Photoperiod will potentially influence the use of molting as an aging device, although the major variation seems to occur *after* the subadult-to-adult molt has been completed. Mohn (1958) described the development of "growth waves" (i.e., ontogenic molts) for the black rat *(Rattus norvegicus)* which are virtually identical to my observations in age at onset, progression, and duration. The similarity of these observations as well as those by other authors suggests that the first few molts (to the adult pelage) are more influenced by ontogeny than other factors. Mohn also comments that the later (adult?) molts are considerably more variable and the frequency and rate are retarded by both pregnancy and lactation.

A microscopic examination of individual hairs and groups of hairs was undertaken. The hairs of one-month-old animals were distinctly shorter and were a mixture of the shorter juvenile hairs and the incompletely grown subadult hairs. Otherwise microscopic examination of the hair was of no value for age determination.

C. Reproduction

The condition of the external reproductive structures was included in the periodic ex-

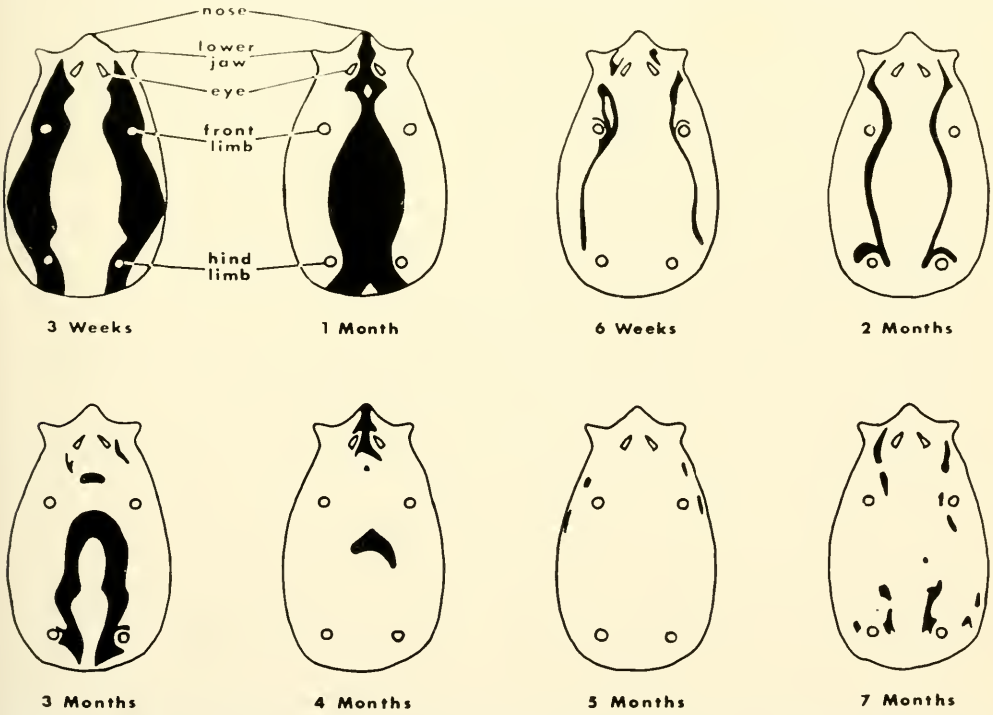


Figure 5. Molt patterns of known-age cotton rats viewed from the skin side of the pelt. Darkened areas indicate areas of active molting.

amination of the live cotton rats. For males the position of the testes (scrotal or abdominal) was determined. The pigmentation and relative size of the teat and the condition of the vaginal orifice (perforate or imperforate) were recorded for each female. Additional data were derived from an examination of the birth dates of litters from known-age parents.

The youngest age at which a rat gave birth was 65 days, having been impregnated by a litter mate. Subtracting a gestation period of 27 days (as determined by Meyer and Meyer, 1944) gives an age at conception of 38 days. This particular individual was the only spring-born (February) female that was used for breeding purposes. All other data on age at first litter are from animals born during September and October. For these individuals the youngest age at which a female gave birth was 84 days, with conception thus occurring at 57 days. The age at conception of the first litter for other females ranged from 70-100 days, with the older age being more common. Meyer and Meyer noted one female being impregnated at 40 days of age and several others by 50 days of age. These authors also noted the first estrus to occur at a younger age during the period January-through-June than during the period September-through-December.

The condition of pregnancy is of value for age determination only to the extent that the investigator can determine a probable minimal age. Furthermore, nonimpregnated females need not necessarily be less than that minimal age. Additionally, Odum (1955) and Haines (1961) have shown that the cotton rat has seasonal reproductive peaks and occasional periods of anestrus, especially during the winter. Presumably photoperiod affects the age at onset of reproductive maturity although other factors undoubtedly exist. Thus pregnancy is at best a limited tool for age determination.

The earliest age at which a perforate vaginal orifice was noticed was six weeks. By three months all females had shown this condition at least once. When sacrificed, one two-month-old female had a distended, fluid-filled uterus, a condition described by Clark (1936) as occurring during proestrus and estrus. An active estrus, as determined by a perforate vaginal orifice or an examination of the uterus, might be more helpful for age determination than pregnancy as it occurs independent of male cotton rats. However, the condition is still influenced by season and, like pregnancy, is of value only for establishing minimal age.

Size and extent of the pigmentation of the teat were constant for females two months or older, except for pregnant and nursing individuals. One-month-old females showed no pigmentation except for the one female mentioned above that bred at 38 days of age. By two months all females showed some pigmentation, and by three months all possessed a dark-brown pigmentation of the teat. A week or ten days prior to the birth of a litter the teats become enlarged and change from dark-brown to black pigmentataion. The dark-brown color returns after weaning if the female is not pregnant. The size and degree of pigmentation of the teat suggest an expression of sexual maturity and activity rather than of age.

Sexual maturity in males can be determined by the presence of viable sperm in the epididymis. No sperm were seen in smears of the epididymis of one month and six-week-old males. The testes normally descend and remain in the scrotal sac at two weeks to one month for laboratory-raised young. Of the five two-month-old males, only two contained sperm in the smeared epididymis. Viable sperm were present in all males three months of age or older. The two earliest pregnancies reported above (conception at 38 days) were by males of the same age as the females. Haines (1961) has shown that male cotton rats vary as much as females seasonally, although I did not notice this. Whatever the variations and their causes, reproductive maturity in males is only indicative of a minimal age of perhaps two months and is thus of very limited value for age determination.

The baculum and its digital processes were studied after maceration and staining. Maceration was considerably hastened by preserving the penis in 40% isopropyl alcohol. Stained specimens were stored in glycerine containing 0.5% phenol to inhibit mold. All bacula were measured with dial calipers. The total length and the height and width of the base were carefully examined, and character indices were attempted. One-month-old animals were distinct, but all older age groups encompassed the same measurements. The staining of the bacula showed a high

degree of uniformity, variations being probably due to staining technique.

Forty-two bacula had digital processes that were satisfactory for study. Of these, 18 were less than seven months of age and showed no deposition of stain in the processes and may thus be assumed to exhibit no ossification. Seven-month-old specimens show a small amount of stain in the tip of the medial process, which increases in extent with age. The lateral processes begin to show staining at nine months, also increasing with age. The extent of the staining is nearly complete at 12 months, showing very little increase at 18 months. The progression of the stained areas is illustrated in Figure 6.

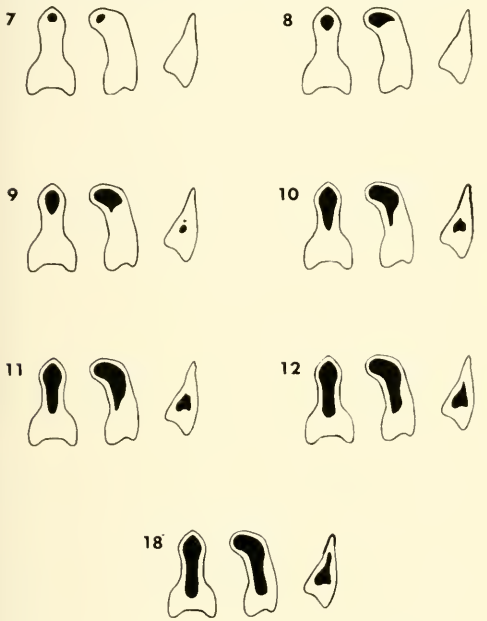


Figure 6. Digital processes from bacula of known-age cotton rats. Number at each group of three indicates the age. The first figure on the left is a ventral view of the median cartilage; the middle figure is a lateral view of the median cartilage; the figure on the right is a ventro-lateral view of a lateral cartilage.

The value for age determination of the staining of the digital processes is limited to male animals over six months of age. In all probability this would be a very small portion of the population. If sufficient numbers of males with ossifying digital processes could be collected, some evaluation of the age composition of the older individuals could be made, especially if one presumes the same age distribution for the females.

D. Teeth

Twelve measurements were made of various individual teeth and tooth rows. The results were effective only to separate one-month-old cotton rats from all older age groups which remained indistinct from each other.

Three subjective tooth characters became evident when measuring the skulls. When viewed laterally, the occlusal surface of the lower molariform teeth appears as a straight line for the younger animals. For the older individuals this view becomes more concave, presumably due to the grinding of the two tooth rows on each other (Fig. 7). Subjective categories with numerical values were applied in an attempt to evaluate this uneven wearing. The technique did not prove successful and was particularly unworkable for very old animals.

The second character was the differential wearing of the first lower molar, the posterior two thirds being ground away more rapidly leaving a short prominence or spike on the anterior third (Fig. 7, C and D). The prominence was categorized numerically but the results were similarly unproductive especially for very old individuals which often lacked the prominence.

The third character was the reentrant angle or groove on the lateral crown surface of the molar teeth. As the tooth is worn away, the groove decreases in length and becomes more exposed. Since the size is too small to measure, I attempted to evaluate the length of the groove as the ratio (expressed as per cent) of this length to the exposed crown height. This evaluation was only made on the first and second molars as the third is partially concealed by the base of the coronoid process. Again the characterization was not significant. The decreased length of the groove is evident in Figure 7.

At the age of one month only eight molars are visible in the cotton rat. The third molar (both mandibular and maxillary) has not yet broken the skin although the tooth is not covered with bone. By two months, the tooth has completely erupted and has attained approximately the same height as the first and second molars.

The occlusal surface is quite constant throughout the life of the cotton rat. The

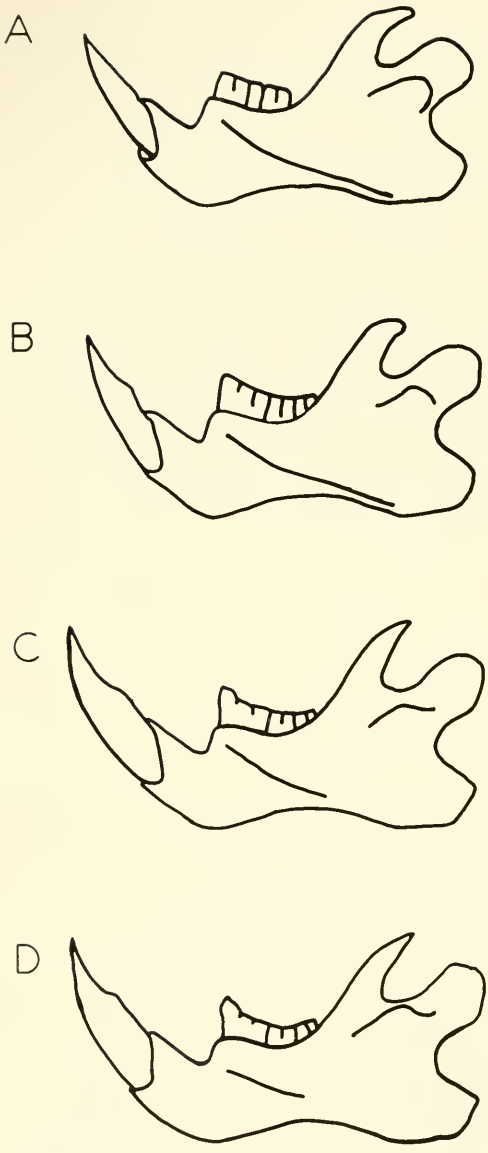


Figure 7. Lower jaws of known-age cotton rats. A—1 month, B—3 months, C—6 months, D—9 months.

changes were more difficult to evaluate than the three subjective categories listed above and thus were of even less value for age determination.

E. Skeleton

Skulls of a male and a female of each age group were randomly selected for a preliminary study of characters that might be useful for age determination, measurements being made with dial calipers. Over thirty measurements were investigated. Measurements of: 1) nasal length; 2) greatest zygomatic breadth; and 3) greatest width of the lambdoidal crest seem to be related to age, and were made on all skulls, as was the condylobasilar length. The data from the four measurements are summarized in Figures 8-11.

For the condylobasilar length (Fig. 8) the data are presented separately for each sex, the males at each age having significantly longer skulls than the females ($P \leq 0.05$ at one month of age; $P \geq 0.02$ at all older ages). For the other three measurements (Figs. 9-11) the differences between the sexes were small although the males were uniformly larger. P values were as low as 0.1 in a few instances but for the most part were 0.3 or greater. The data do not warrant being

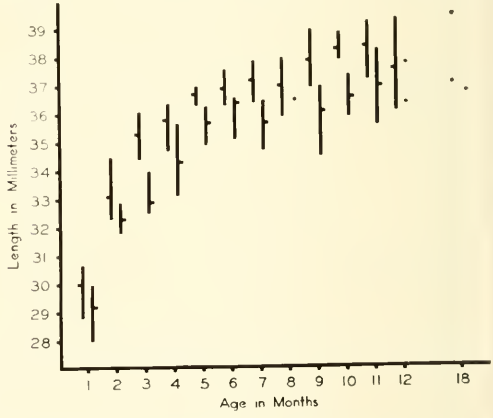


Figure 8. Condylobasilar length of known-age cotton rats by sex. (See Figure 1 for description.)

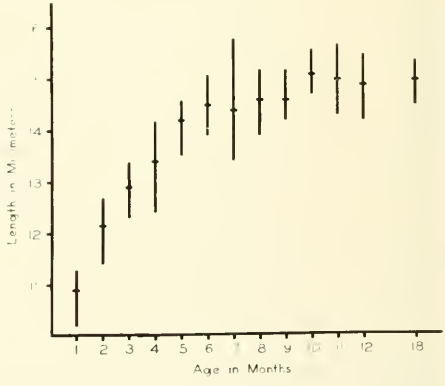


Figure 9. Nasal length of known-age cotton rats. (See Figure 3 for description.)

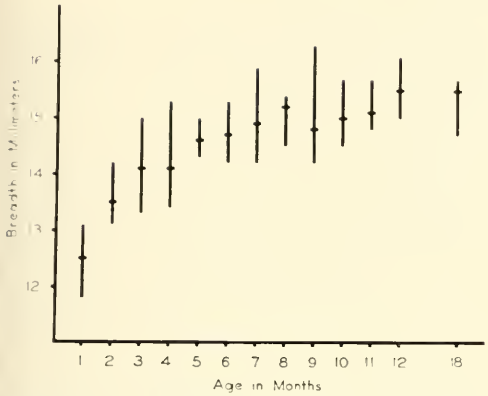


Figure 10. Lambdoidal breadth of known-age cotton rats. (See Figure 3 for description.)

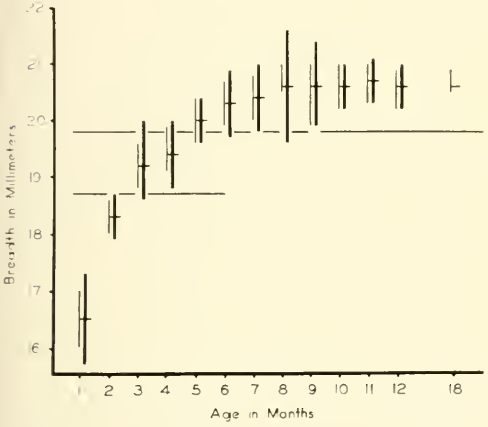


Figure 11. Zygomatic breadth of known-age cotton rats. The thinner, vertical line on the left of each symbol represents the range of the data. The heavier, vertical line on the right of each pair represents two standard deviations on either side of the mean, which is indicated by the horizontal line.

separated by sex especially considering the small sample size.

The measurement of the most apparent value for age determination is the zygomatic breadth (Fig. 11). For this measurement the standard deviation was computed and added to the figure as two standard deviations on either side of the mean. This procedure was used to determine the validity of the sample as the two standard deviations would thus represent ninety-five per cent of the population and provide more comparison than the actual ranges.

By inspection one-month-old individuals are distinct from all other groups. The two-month-old individuals are nearly distinct. A line has been added to the figure at 18.7 mm to separate the two-month-old individuals from older specimens. The overlap of the data is in the standard deviation only, the ranges being distinct. Three- and four-month animals together form a group which is largely separable from the rest of the animals in this study. A second line has been added at 19.8 mm which, although arbitrary, separates most of the three- and four-month specimens from most older individuals.

Thus, four age groups can be identified: 1) one-month-old individuals; 2) two-month-old individuals; 3) three- and four-month-old individuals; and 4) individuals five months or older. These categories have virtually no overlapping of the ranges. The sample size is undesirably small, perhaps accounting for a large standard deviation.

Alexander (1960) has shown that there is approximately a 1.5% decrease in the zygomatic measurement of the muskrat as the skull dries. This shrinkage in cotton rats would amount to 0.3 mm of a zygomatic breadth of 20 mm. Since all skulls were cleaned and measured at the same time, the shrinkage should be uniform and the data still valid. Presumably standard cleaning and measuring techniques should be used when making this measurement on a population sample. Character indices also were computed by various combinations of the four measurements, but the applicability of the data was not increased.

Older animals exhibit a general increase in the development of the ridges or crests of the skull. The ridges appear to attain most of their development by three or four months, although the skull still appears to become more massive throughout the age groups. However, with the exception of the breadth of the skull at the lambdoidal ridge, all measurements to evaluate this increased size were unsuccessful. Weighing the skulls only served to distinguish one-month-old individuals as a group. Furthermore, when guessing the age of an individual skull by examination of the development of its ridges and its weight, I was successful only with one- and two-month-old individuals. Thus, while subjectively evident, the ridges defy objective measurements and are concluded to be of little value for age determination.

The mandibular weight permitted the identification of both one- and two-month-old animals as groups distinct from the rest of the specimens. The limited value of this measurement does not justify the time spent in the careful cleaning of the mandible before weighing.

The forelimb was studied extensively for areas of epiphyseal fusion that would be of value for age determination. The results described below are a composite of both the maceration and X-ray data, the former being the more easily studied. At one month the distal epiphyses of the metacarpals are distinguished from the diaphyses by a nonstaining band of cartilage, which by two months is reduced to a deeper staining suture line. This line becomes indistinct at three months and is absent at four months of age.

The sesamoid bones of the metacarpal-phalanx joint first become apparent by staining at three months of age, but are distinct from the two bones of the digit. At four months the sesamoids are beginning to fuse with the metacarpals, which process is completed at five months of age.

A second series of sesamoids can be seen at four months, at the distal end of the proximal phalanx. Like the first series these bones are fused to the proximal phalanx two months later at an age of six months.

The distal epiphyses of the radius and ulna at one month are distinct and separated from the diaphyses by a clear nonstaining band of cartilage. For animals two months of age the epiphyses are separated only by a line lacking in stain. The epiphyseal suture is about one-half ossified at three months. The process is virtually completed at four months although a suture line is visible in all older specimens and shows very little change. Green (1949) also has noted the persistence of this suture line to older ages in the Norway rat.

The proximal epiphysis of the ulna is very similar to the distal epiphyses of the radius and ulna, clearly distinct at one month and largely ossified to the diaphysis at four months of age. A suture line is similarly present in all older specimens.

The acromion process of the scapula shows no ossification at one month of age and only a small distal area of stain deposition at two months. The amount of ossification gradually increases so that the process is largely if not completely ossified at five months. A suture line is still visible for a few months, but is absent in all specimens nine months or older.

The suprascapular cartilage is also unstained at one month of age. At two months a small area of staining appears at the corner of the glenoid and vertebral borders of the scapula. By three months the suprascapular cartilage is ossified about one half its length, but a narrow stain-free area separates the ossifying cartilage from the scapula. At five months of age the cartilage is largely ossified, and only at this time does the suprascapular cartilage begin to fuse to the scapula. This later process continues slowly and is not complete even in the twelve-month animals.

The ossification processes are not all complete at six months, but at this age the changes are very slow and irregular. These later stages of ossification and fusion are of very limited value for age determination and are not discussed. All the described areas of ossification are summarized in Figure 8. Other epiphyseal areas exist in the forelimb, but these are either difficult to distinguish, such as the epiphyseal areas of the humerus, or proceed too rapidly to be diagnostic, such as is seen in the epiphyses of the phalanges.

The tail also was X-rayed to study the degree of ossification and fusion of the intervertebral discs. This procedure was investigated as the tail can be X-rayed easily on a live, anesthetized animal where an examination without injury is highly desirable.

For the younger animals the caudal intervertebral discs are largely unossified to the centra of the vertebrae. Those that are nearest the pelvis ossify first. The degree of ossification increases with increasing age of the specimen, although it is never complete. Even in the twelve-month-old specimens the last few (three to six) discs remain quite distinct. The major difficulty in evaluating the data is deciding which discs have begun to show ossification in order to produce numerical or even reasonably objective data. No satisfactory method was found. The problem was compounded due to the X-ray film used and its inability to produce a sufficiently sharp outline of the structure.

The use of epiphyseal fusion gives promise as an aging device. While the best data are derived from the examination of macerated material, the use of X-rays is encouraging

and should be investigated further. If macerated limbs are used, a good estimation of age can be made by the examination of the seven areas of bone development (Fig. 12).

F. Lens Weight

All lens weights discussed are the combined weight of both lenses. The technique employed here is that described by Lord (1959). Each age group was examined for sexual dimorphism. Except for the ten-month-old group discussed below, no significant differences exist between the sexes ($P>0.3$). The data for both sexes are therefore considered as a single sample for each age, the larger sample size permitting a better mathematical comparison of the age groups. Lord likewise noted no differences between males and females and considered both sexes as a single sample.

The ranges and means for the data are presented in Figure 13. The standard deviation has been computed for each age group and added to the figure as two standard deviations on either side of the mean. This method of evaluation is especially justified since the standard deviations exceed the range of most samples.

The one-month-old sample is quite distinct. The two-month-old sample is nearly so, a small overlap of the standard deviations occurring between the two- and three-month samples. Animals up to three months, therefore, could be quite correctly aged by this technique. For all older age groups, both the range of the sample and the area covered by the two standard deviations show at least some contiguity, especially for those groups six months or older.

Older age groups might be distinguished by making arbitrary weight values to separate them. Accordingly, horizontal lines have been added to Figure 13 at 25 and 33 mg. This permits isolation of a four- and a five-month-old age group from the three-month age group and the age group six months or older. Thus a total of five age classes can be established. Of the 62 individuals in the one- through six-month-old age groups, only three, or less than 5%, thus fall into incorrect classes. Therefore, the dry lens weight would appear to be a very satisfactory technique for age determination.

For the successful application of any aging technique, one should be aware of possible variations and their causes. The 10-, 11-,

	1	2	3	4	5	6
D. Epiphysis, Metacarpal	Separate	Fusing	Fused to Metacarpal			
Sesamoid, Metacarpal	Nonstaining		Stained	Fusing	Fused	
Sesamoid, P. Phalanx	Nonstaining			Stained	Fusing	Fused
D. Epiphysis, Radius, Ulna	Separate	Fusing		Fused	Suture Line Visible	
P. Epiphysis, Ulna						
Acromion Process	Nonstaining	$\frac{1}{8}$ Stained	$\frac{1}{3}$ Stained	$\frac{2}{3}$ Stained	Suture Line Visible	
Suprascapular Cartilage	Nonstaining	$\frac{1}{4}$ Stained	$\frac{1}{2}$ Stained	$\frac{3}{4}$ Stained	Fusing to Scapula	

Figure 12. Summary of data on epiphyseal fusion. The numbers at the top indicate the age in months.

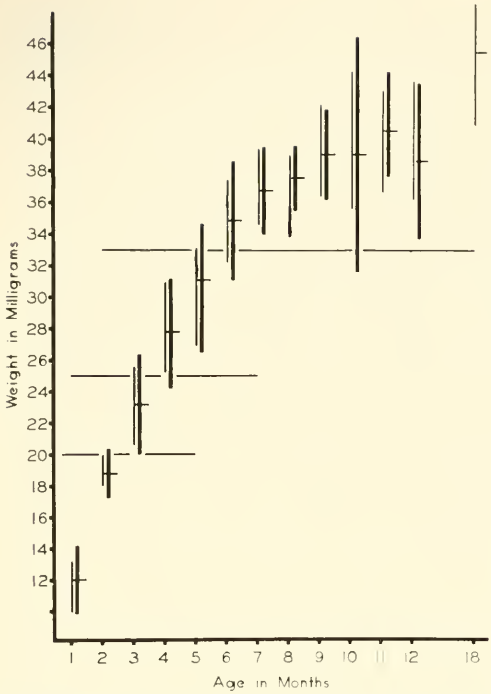


Figure 13. Dry lens weight of known-age cotton rats. (See Figure 11 for description.)

and 12-month-old samples offer some insights to the problem. The limits of the two standard deviations of the 10-month sample considerably exceeded the observed range, admittedly large itself. The individuals constituting this sample fall into two groups: one of six females whose lens weights range from 35.6-37.8 mg, and a second group of three males whose lens weights ranged from 43.9-44.3 mg. This is the only age group where distinct differences occur between the sexes. Perhaps a more reasonable explanation is that the females were not autopsied until several days after being sacrificed, although the specimens were frozen. Montgomery (1963) has shown that raccoon lenses lose weight after being frozen for several days before autopsy.

For the 11-month-old sample, one individual born in May and sacrificed the following April had a lens weight of 36.7 mg. The remaining individuals of this sample were born in September and sacrificed the following August. These individuals had lens weights ranging from 40.4 to 43.2 mg. The 12-month-old samples contained one group of seven individuals born and sacrificed in May whose lens weights ranged from 36.2 to 39.4 mg. The remaining four individuals of the sample were born and sacrificed in September and had lens weights of 39.6 to 43.8 mg. None of the specimens were frozen prior to autopsy. An explanation of the differences in weight might be variation induced by the day length since the animals, born in different seasons, were subjected to the normal day length throughout this study. Also, since the animals were from several different litters this range of weight might simply indicate normal variation in the older animals.

G. Field Study

The last phase of this study was an attempt to obtain accurate growth data from the natural habitat to be compared to the laboratory-derived growth curves which could then be evaluated and adjusted. An old field habitat was selected for releasing four-week-old laboratory-raised animals. The area had been trapped intermittently over a period of two years and was known to be suitable for cotton rats. For two months before releasing the young animals I made several trips to the area to trap out as much of the existing small mammal fauna as possible, reducing competition for the young cotton rats. During the retrapping period following release of the young, only one nonmarked cotton rat was collected.

Each cotton rat to be released was toe-clipped for identification when weaned. Three or four cotton rats from the same litter were then placed in a new cage. In place of the usual tin-can nesting facilities the animals were provided with a wooden nest box approximately 6 x 6 x 4 inches high. A 2 x 2 inch opening was provided with a cover that could be closed quickly with the cotton rats inside. The nest box was transported to the release area, the cover opened, and the animals left with an available nest to which they might be accustomed. A liberal supply of food was also placed in the nest box. I had hoped that some individuals would continue to use this shelter and thus facilitate their recapture. Many of the nest boxes appeared to be inhabited as grass and cuttings were incorporated into the nest box cotton. However, only one cotton rat was ever found in the nest box and this individual escaped before the opening could be covered. A total of 96 rats were released from March 25 to June 5, 1961.

During May the release area was exhaustively retrapped on three occasions with collapsible Sherman live traps. Approximately 200 traps were set each of the seven nights involved. The release area was also live-trapped in mid-June for five nights continuously with 240 traps per night, prior to which heavy rains had inundated the release area. No cotton rats or any other small mammals were collected during the latter period. The field project was terminated at this time for lack of additional young available for release.

Cotton rats trapped in May were etherized, weighed, and measured, and examined for molting and reproductive status. They were then allowed to recover for 30 minutes and released at the same location where they were trapped. Of the 96 rats released, 12 were recaptured from one to four times for a total of 23 recaptures. Four individuals died in the live traps, presumably from the high temperature due to direct sunlight on the traps and from attacks by fire ants. The remains of the four that died were autopsied as far as possible. The date on these four animals are given in Table 2.

The weights and body lengths of all retrapped cotton rats are plotted in Figures 14 and 15. If an individual was retrapped on several consecutive days, only the first day is plotted. Two individuals were recaptured a second time, 22 days after their first recapture. These points are connected with a line for identification.

As expected, weight increase was much slower in the field than in the laboratory. The lines on Figure 14 represent the *minimum* weight of the monthly laboratory sample of each sex. The mean weight was so much greater that plotting it on the chart would have had no value for comparison.

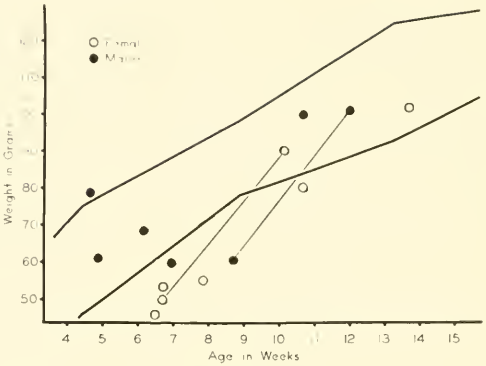


Figure 14. Body weights of released known-age cotton rats. The heavy line represents the *minimum* monthly weights from Figure 1 (upper line for males; lower line for females). The thin lines connect data for the same individual.

The difference between the laboratory and field studies probably is due to increased activity in search for food—food that also is less likely than the laboratory diet to be accumulated as body fat. Possibly the stress induced by being released into an unfamiliar and competitive habitat and/or being in the live-trap for extended periods may have affected the body weight. Animals recaptured on successive days showed weight losses from previous days of up to five grams. The information on body weights is too limited to construct a growth curve of wild animals. The data do strongly suggest that laboratory weights are of little use for age determination of wild individuals.

The body length measurements are plotted in Figure 15. The lines in this figure represent the *average* body length of each monthly sample. The field data appear to be quite consistent with the laboratory data, and substantiate the idea that the greater body

TABLE 2.

Data on released animals that died in the live traps. Skull measurements in millimeters; lens weights in milligrams.

Animal No.	356	382	426	445
Sex	m	f	f	f
Age (days)	85	75	45	55
Condylobasilar length	34.0	32.6	30.5	32.4
Nasal length	12.7	12.1	11.1	12.5
Lambdoidal breadth	13.6	13.3	13.0	13.2
Zygomatic breadth	18.8	18.4	17.6	18.0
Lens weight	22.8	*	13.4	*

* Data not available

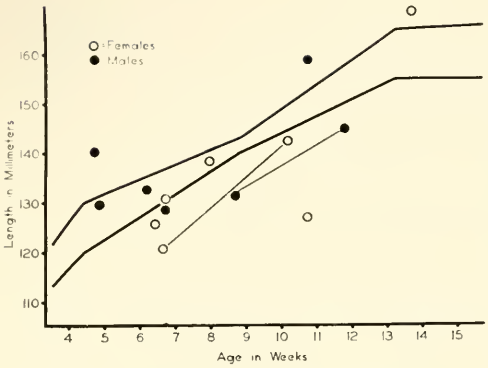


Figure 15. Body length of released, known-age cotton rats. The heavy lines represent the *mean* body lengths from Figure 2 (upper line for males; lower line for females). The thin lines connect data for the same individual.

weights of laboratory animals reflect a greater amount of fat and not larger size. On the basis of these limited data, body length appears to be a useful method for age determination.

Five cotton rats were found to be molting when recaptured. Two individuals (33 and 34 days old) were completing the subadult molt. Two others (61 and 75 days old) were in the earlier stages of the adult molt. A single recapture at 84 days of age was molting dorsally, thus completing the adult molt. Five individuals captured at 43-47 days of age were not molting. Presumably they were in complete subadult pelage and would shortly begin to molt to the adult pelage. The cotton rat examined at 96 days was not molting. The individual molting data of the released animals coincide well with the observed laboratory data except that the subadult-to-adult molt may begin somewhat later and end somewhat earlier. With more field studies and an increased understanding of seasonal variation, the molting pattern for age determination could possibly be developed to a high degree.

The reproductive data are limited. One male died in the trap (age 84 days). A smear of the testis and epididymis was negative but this is attributed to the carcass being severely damaged by fire ants and the length of time between death and microscopic examination. All males when recaptured had the testes in the scrotal position.

One female captured at 96 days of age had considerably enlarged teats and was lactating. The vaginal orifice was imperforate which suggests that parturition had occurred one or two days previous to capture. With a normal gestation period this female probably mated at about 65 days of age. This single example of reproductive activity of a released female agrees well with the laboratory data. The reproductive tracts of the three females that died in the live traps did not show any indication of reproductive activity.

The teeth of the four released cotton rats that died in the traps showed the most dramatic difference from the laboratory study. Staining of the teeth, presumably due to the diet, is very marked. The teeth are considerably more worn than laboratory individuals of the same age. Using laboratory tooth wear as a criterion for age determination produces an estimate two-to-four months older than the actual age. Since tooth wear is more rapid in the natural habitat, this character might be used successfully for aging, as more variability would be present and thus more stages of wear that possibly would reflect the animal's age.

The skeletal characteristics of the released cotton rats compare well with the laboratory data. The skull measurements are listed in Table 2. The condylobasilar and nasal lengths both fall in the lower range of the known-age measurements. The lambdoidal breadth and the zygomatic width show very satisfactory agreement with the laboratory data. A good age estimation can be obtained on the basis of these two measurements..

The characteristics of the stained forelimb are in consistent agreement with the laboratory data. The metacarpal and phalangeal epiphyses, the distal epihyses of the radius and ulna, the proximal epiphyses of the ulna, and the ossification of the acromion process and the suprascapular cartilage are all in close agreement with the laboratory data. These limbs were examined initially without the knowledge of the specimen's exact age. The 45-, 55-, and 75-day-old specimens were all estimated to be "about two months" while the 85-day-old individual was estimated to be "three months." These estimations appear to be as accurate an estimation as could be made with any character.

The lens weights of only two of the four dead known-age individuals were in satisfactory condition for study. The eyes of the

others were dried out and partially eaten by ants. As can be seen by comparing the lens weight from Table 2 with those in Figure 13, the data from the released cotton rats fit the laboratory data quite satisfactorily.

V. Discussion and Conclusions

When considering the reliability of age determination based upon laboratory data, two points must be kept in mind. First, animals are not found in month-old groups but form a continuum of all ages. Thus, while one may attempt to assign an animal to a certain age group one does so with the knowledge that the age of the animal is being approximated only. The second point is estimating age from a live or a dead animal. In a live-trap study one must determine the age and then release the animals unharmed. Such a procedure limits the number of characters that can be employed. The present study was based largely upon the interpretation of characters from dead animals. I presumed that some dead-animal characteristics could be adapted to evaluate living cotton rats. One possible adaptation would be the use of X-raying in place of the maceration and staining technique.

From an examination of the data that have been presented it appears that age determination can be accomplished best for animals up to six months of age by a combination of several characters. Age determination of older cotton rats appear virtually impossible other than to indicate an individual as being over six months of age. Precisely what age cotton rats may attain in their natural habitat is, of course, unknown. Some information on this topic has been presented by Odum (1955), who stated that an animal once trapped was never retrapped more than six months later. Assuming such an individual to be a month old or more when initially trapped, its maximum age when retrapped would probably not exceed seven to ten months. In a live-trapping study of the cotton rat in Louisiana in which I participated, cotton rats were never retrapped more than four months after the initial trapping. Recently Dunaway and Kaye (1964) did note two wild cotton rats approximately 10 and 11 months of age. It is not known how many other rats attained such an age.

The techniques developed in this study are felt to be satisfactory for estimating the age of wild cotton rats throughout the greater portion of their presumed life expectancy. However, any attempt to estimate age should be based on several characters to minimize error. The most reliable characters are summarized in the following two paragraphs.

The computed body-length measurement is rapidly collected and is satisfactory to separate animals up to three months of age from all other animals of the population. Molting might also be used to distinguish the younger age categories, although the distinctions are less specific than body length, and the process is more easily studied from the skin side of the pelt. The molting pattern continues to change fairly regularly in the laboratory specimens, but the information is probably inadequate for use as a critical age-determining characteristic, as molting has been shown in other rodents to vary with the seasons of the year. This particular character definitely should be studied in more detail under more varied laboratory conditions and in the natural habitat.

Epiphyseal ossification can be determined on a dead animal by maceration and staining. By comparing the several ossification areas, one can establish the approximate age of an animal to six months of age. For a live animal, epiphyseal ossification might be studied by X-raying the limb of an anesthetized animal. This character may have considerable advantage as an age-estimating technique, as ossification processes seem to proceed at a fairly constant rate and presumably are not as subject to environmental variation as are body weight and molting. One additional charatcer that might be developed for determining the age of a live cotton rat is the measurement of the zygomatic breadth. This character was studied only on clean skulls but proved quite accurate for estimating age. Since the amount of flesh covering the zygomatic arch of the live animal is quite limited, this measurement might be adapted for estimating age. The lens weight data are very useful for age determination. There is no clear separation of the four- and five-month-old animals, but these two ages are distinguishable from all younger age groups and from all older animals. As the moment nothing is known of the factors, other than freezing, that may cause variation in the lens weight. Thus by a combination of the above techniques, one should be able to closely approximate the

age of a given animal based upon the laboratory data.

One very difficult problem to evaluate is the difference between growth of a laboratory specimen and growth of a wild specimen in its natural habitat. That such a difference exists is easily shown by the fact that the laboratory cotton rats used in this study were considerably heavier than their counterparts released in the field at an age of 4 weeks. However, this may be only part of the picture. Unknown and impossible to evaluate is the effect of preweaning growth on the cotton rat before it is released. All cotton rats, prior to release, received what might be considered an adequate if not optimal diet. Presumably by this time the subsequent growth pattern has been largely determined. Similarly difficult is the problem of evaluating the health and nutrition of the female cotton rat prior to conception. A female in good health could be expected to produce healthier young than a female in poor health. Thus not only the early preweaning growth but even the prenatal development of the animals that were released was undoubtedly affected by the laboratory environment. One possible mechanism for evaluating such changes would be to collect pregnant cotton rats from the field and allow them to have their litters in the laboratory. Immediately after birth the animals could be toe-clipped, and then the female and her litter released into the natural environment, possibly in a large enclosure. Dunaway and Kaye (1964) toe-clipped young cotton rats born in live traps. Presumably these individuals are the known-age animals they discuss. This method is the best way of obtaining known-age animals in their habitat, although perhaps limited in numbers of individuals.

Several studies have attempted to estimate the age of the cotton rat. Erickson (1949) classified each individual as either immature or adult but did not give any basis for these age classes. Since the basic purposes of the study were calculations of movement and density, age determination was not particularly important.

Similarly, Stickel and Stickel (1949) studied the home range of the cotton rat in Texas. They recognized four age classes based primarily on size and breeding condition. Only approximate body-length measurements were taken, and these were not listed by the authors. The age classes were thus rather subjectively determined. Their two youngest age classes probably correspond to one- and two-month-old animals as used in this study.

Sealander and Walker (1955) conducted a study of the cotton rat in northeastern Arkansas. Age classes were initially defined on the basis of actual or potential reproduction. Thirty days was considered the age at which cotton rats might begin breeding. The laboratory growth data of Meyer and Meyer (1944) were then employed to form weight limits to each age class. The age classes were subadult, 10 to 29 days; young adult, 30 to 50 days; old adult, 51 to 250 days. On the basis of the age classes as determined by using body weight, these authors found an age distribution during the late winter and early spring that indicated a high percentage of young individuals in the population. This, in spite of the fact that breeding had ended the previous November and had not yet resumed. Thus weight used as an age criterion did not produce an age distribution that agreed with the field data. These authors also noted that considerable body fat accumulated by the cotton rats in November and December, declined drastically in January and February to about 60% of the peak December value, and disappeared in April. Presumably this body fat is used as an energy source during the period of its decline. Thus, while the animals are actually becoming older they are losing weight, a fact which would place animals in younger age categories. In theory, weight might be used as an aging technique during the severe winter period if one could take into consideration the probable weight loss in each individual at this time. However, it would be incorrect to assume that the same rate of body weight decline is present during each winter.

Odum (1955) concurrently studying cotton rat populations over a period of 11 years, presents data that may give a truer picture of the normal weight gain. He captured a 15-gm female on June 6, 1949. On the basis of an average birth weight of 7 gm and a gain of 1 gm a day (Svihla, 1929; Meyer and Meyer, 1944), the above individual was adjudged to be a week old when captured. It was recaptured on August 21, at a presumed age of 159 days and a weight of 96 gm. A second female weighed 74.5 gm on

August 21, and two and one-half months later, on November 9, weighed 103 gm. Judging from my release records, this second female was two to three months old when first caught and, therefore, about five months old at the weight of 103 gm. While limited, the data do give some idea of the rate of weight gain by wild cotton rats. According to the weight limits of the age categories employed by Sealander and Walker, these two females would have been classified as young adults (age 30-50 days).

Odum's study of cotton rat populations was based largely on spring (May) and fall (November) trapping. The primary purpose of his study was to follow the periodic changes in population density. The trapping program employed served the purpose well, as Odum's methods avoided the problematic period of winter weight loss.

Dunaway and Kaye (1964) mention a male and two female cotton rats weighing 103, 95, and 101 gm, respectively, at an age of 104 days when trapped in November. A male and a female 119 days of age when captured in February weighed only 88 and 77 gm, respectively, however, and a 117 day old male weighed only 75 gm at this time. Also, a female, age unknown, weighed 62 gm in September, 87 gm in November, but only 84 gm in February. In addition to emphasizing the severe effects of winter, the data point out the impossibility of using laboratory weight for age estimation. The three 3½-month-old cotton rats trapped in November fall in the weight range of 2 month old laboratory rats. Using Odum's (1955) criteria, these animals would have been placed in the 2-to-5-month-old category.

The information on growth rates and reproductive activity of known-age individuals in the natural habitat is too limited for specific conclusions. However, where available, data from cotton rats released in the present study either show close agreement with the laboratory data or else give indication that the laboratory data might be modified to allow for an adequate age estimation. Body weight is a useful age-determining technique at certain seasons of the year, but should not be employed during the period January-through-April except with extreme caution. The other techniques described in this study should be more useful than weight for age determination, especially during the winter. Finite evaluation of age-determining techniques should be based on releasing and retrapping young known-age individuals at all seasons of the year.

VI. Acknowledgements

I wish to express my sincere appreciation to the following people: Dr. Norman C. Negus under whose direction this study was carried out; Robert C. Feuer and Dan Goldberg for timely assistance in the laboratory and field; and my wife for patience, encouragement, and assistance in all phases of this study.

VII. References Cited

Alexander, Maurice M. 1958. The place of aging in wildlife management. *Amer. Sci.* 46: 123-137.

. . . . . 1960. Shrinkage of muskrat skulls in relation to aging. *J. Wildl. Mgmt.* 24: 326-329.

Clark, Frank H. 1936. The estrous cycle of the cotton rat. *Contr. Lab. Vert. Genetics.* No. 2. 2 pp.

Dunaway, P. B., and S. V. Kaye 1964. Weights of cotton rats in relation to season, breeding and environmental radioactive contamination. *Am. Midland Naturalist,* 71: 141-155.

Erickson, Arnold B. 1949. Summer populations and movements of the cotton rat and other rodents on the Savannah River Refuge. *J. Mammal.* 30: 133-140.

Green, Eunice C. 1949. Gross anatomy. In: *The Rat in Laboratory Investigations.* Edmond J. Farris and John G. Griffith, Jr., editors. Second edition. J. B. Lippincott Co., Philadelphia, i-xiv; 1-542.

Haines, Howard 1961. Seasonal changes in the reproductive organs of the cotton rat, *Sigmodon hispidus. Texas J. Sci.,* 13: 219-230.

Keys, Charles E. 1958. The rate of development of *Sigmodon hispidus* as compared with some other rodents. *Trans. Kentucky Acad. Sci.,* 19: 25-27.

Lord, Rexford D., Jr. 1959. The lens as an indicator of age in cottontail rabbits. *J. Wildl. Mgmt.,* 23: 358-360.

McIntire, J. M., B. G. Schweigert, and C. H. Elvehjem 1944. The nutrition of the cotton rat *Sigmodon hispidus hispidus. J. Nutrition,* 27: 1-9.

Meyer, D. B., and Martha Marsh 1943. Development and management of a cotton rat colony. *Am. J. Publ. Health,* 33: 697-700.

Meyer, B. J., and R. K. Meyer 1944. Growth and reproduction of the cotton rat *Sigmodon hispidus hispidus* under laboratory conditions. *J. Mammal.,* 25: 107-129.

Mohn, Melvin P. 1958. The effects of different hormonal states on the growth of hair in rats. In: *The Biology of Hair Growth*, pp. 335-398. William Montagna and Richard A. Ellis, editors. Academic Press Inc., New York. i-xvii, 1-520.

Montgomery, G. G. 1963. Freezing, decomposition and raccoon lens weight. *J. Wildl. Mgmt.*, 27: 481-483.

Odum, Eugene P. 1955. An eleven year history of a *Sigmodon* population. *J. Mammal.*, 36: 368-378.

Rabasa, S. L. 1952. Growth rate of the white rat in relation to the number per cage. *Physiol. Zool.*, 25: 98-103.

Sealander, John A., Jr., and Barry Q. Walker 1955. A study of the cotton rat in northwestern Arkansas. *Proc. Arkansas Acad. Sci.*, 8: 153-162.

Stickel, Lucile F. and William H. Stickel 1949. *A Sigmodon* and *Baiomys* population in ungrazed and unburned Texas prairie. *J. Mammal.* 30: 141-150.

Svihla, Arthur 1929. Life history notes on *Sigmodon hispidus hispidus*. *J. Mammal.*, 10: 252-253.

Digenetic Trematodes of Marine Fishes From Apalachee Bay, Gulf of Mexico

FUAD M. NAHHAS*
and
ROBERT B. SHORT,
Department of Biological Sciences,
Florida State University,
Tallahassee, Florida

CONTENTS

I. Abstract 39
II. Acknowledgments 39
III. Introduction and Methods 40
IV. Description and Discussion of Species 40
Family Aporocotylidae 40
Family Bucephalidae 40
Family Fellodistomatidae 41
Family Haplosplanchnidae 41
Family Gorgoderidae 41
Family Opecoelidae 41
Family Lepocreadiidae 42
Family Cryptogonimidae 44
Family Acanthocolpidae 45
Family Hemiuridae 45
Family Sclerodistomidae 48
V. Summary 48
VI. Alphabetical Host-Parasite List 48
VII. List of Fishes Negative for Trematodes 49
VIII. References Cited 49

I. Abstract

Forty-eight species of Digenea are reported from 43 species of fishes from Apalachee Bay, Florida. Three new species are described: *Genitocotyle cablei* (Opecoelidae), *Lepocreadium brevoortiae* (Lepocreadiidae) and *Pseudoacanthostomum floridensis* (Cryptogonimidae). Fourteen new locality records bring to 109 the species of Digenea known from Tampa Bay and the northern Gulf: 27 species from the Texas coast, 50 from Louisiana, 16 from Mississippi, 31 from Tampa and Boca Ciega Bays, and 48 from Apalachee Bay.

* Present address: Department of Biological Sciences, University of the Pacific, Stockton, California.

II. Acknowledgments

Thanks are due a number of people, particularly Professor Ralph W. Yerger for the identification and nomenclature of fishes, and to Mr. Theodore Booden and Mr. Edwin Powell for assistance in the collection of material. The authors also wish to acknowledge the financial support of the Institute of

Editorial Committee for this Paper:

Raymond M. Cable, Professor of Zoology, Department of Biological Sciences, Purdue University, Lafayette, Indiana

Harold W. Manter, Professor of Zoology, Department of Zoology and Physiology, University of Nebraska, Lincoln, Nebraska

Franklin Sogandares-Bernal, Associate Professor of Zoology, Department of Zoology, Tulane University, New Orleans, Louisiana

Molecular Biophysics of the Florida State University during residence of the first author as a postdoctoral fellow in the Department of Biological Sciences.

III. Introduction and Methods

Work on the adult digenetic trematodes of marine fishes of the Gulf of Mexico has been summarized or reviewed by Manter (1954) and Sparks (1960). To date 190 species are known from Tortugas compared with 87 from other parts of the Gulf: Tampa and Boca Ciega Bays (31), Mississippi (16), Louisiana (50), and Texas (27). In contrast, only four species have been reported from Apalachee Bay in the northeastern part of the Gulf. Short (1953, 1954) reported two new species of aporocotylids, Kruse (1959) redescribed *Opecoeloides fimbriatus* (Linton, 1934) Sogandares-Bernal and Hutton, 1959, and Riggin and Sparks (1962) described a new bucephalid. The present paper adds 44 species to the Apalachee Bay; some are reported for the first time from the Gulf of Mexico. Not included are six species of monorchiids and zoogonids which will be reported elsewhere. The present survey was conducted mainly over a 10-week period during the summers of 1963 and 1964, and consists of the examination of more than 300 individuals representing 63 species of fishes, taken from Alligator Harbor, Mud Cove, Dog Island Reef, off St. Marks light house, and off St. George Island in the Apalachee Bay. The fishes were obtained by several methods including traps, nets, line, and the use of rotenone. Hosts were examined shortly after their death; in a few instances their viscera were kept in 0.7% saline for less than six hours in jars placed on ice. The worms were washed in saline, studied alive whenever time permitted, and fixed in Alcohol-Formalin-Acetic acid (A.F.A.) under light cover slip pressure. An attempt was made to relax some of the trematodes in chloretone before fixation, but the results were not satisfactory, particularly in the case of the hemiurids. The specimens were stained with either Semichon's carmine, Harris' haematoxylin, or Ehrlich's acid haematoxylin, dehydrated in a graded series of ethyl alcohol, cleared in terpineol, and mounted in damar. Figures were drawn with the aid of a microprojector or a camera lucida, except for Figure 5 which was traced from a photograph. Measurements are in millimeters except where indicated otherwise. All host names are those used in American Fisheries Society Special Publication No. 2, 1960, "A list of Common and Scientific Names of Fishes from the United States and Canada." Holotypes of new species as well as specimens of some known ones are deposited in the U. S. National Museum Helminthological Collection. An asterisk indicates a new host record; two asterisks, a new locality record for the northern Gulf.

IV. Description and Discussion of Species

FAMILY APOROCOTYLIDAE Odhner, 1912

Cardicola laruei Short, 1953

Hosts: Cynoscion arenarius; C. nebulosus
Site: heart
Localities: Alligator Harbor; St. George Island

Selachohemecus olsoni Short, 1954

Host: Scoliodon terrae-novae
Site: heart
Locality: Alligator Harbor

This species was not found in the present study but is listed to give a more complete record of adult trematodes of the area.

FAMILY BUCEPHALIDAE Poche, 1907

Bucephalus varicus Manter, 1940

Hosts: Caranx crysos; C. hippos
Site: ceca
Localities: Alligator Harbor; Dog Island Reef

Bucephaloides arcuatus (Linton, 1900) Hopkins, 1954**

Synonyms: Gasterostomum arcuatum Linton, 1900; *Gasterostomum* sp. Linton, 1900; *Bucephalopsis arcuatus* (Linton) Eckman, 1932

*Hosts: *Pomatomus saltatrix; Scomberomorus maculatus*
Site: intestine
Locality: Dog Island Reef
Deposited specimen: U.S.N.M. No. 60080

Bucephaloides bennetti Hopkins & Sparks, 1958

Host: Paralichthys albigutta
Site: intestine
Locality: Alligator Harbor

Bucephaloides caecorum Hopkins, 1956
Host: Bairdiella chrysura
Sites: ceca and intestine
Locality: Alligator Harbor

Bucephaloides megacirrus Riggin & Sparks, 1962
Host: Sciaenops ocellata
Site: intestine
Locality: Alligator Harbor

Rhipidocotyle baculum (Linton, 1905) Eckman, 1932**
Synonyms: Gasterostomum baculum Linton, 1905; *Gasterostomum* sp. Linton, 1900; *Nannoenterum baculum* (Linton, 1905)
Host: Scomberomorus maculatus
Site: intestine
Locality: Dog Island Reef

Rhipidocotyle transversale Chandler, 1935
Synonym: Prosorhynchus grascilescens (Rud.) of Linton, 1940
*Hosts: Strongylura marina: *S. notata*
Site: intestine
Locality: Alligator Harbor

Prosorhynchus atlanticum Manter, 1940**
Synonym: Gasterostomum sp. Linton, 1910
Host: Mycteroperca bonaci
Site: intestine
Locality: Alligator Harbor
A single specimen was found; eggs measured 32-35 by 21-23 microns.

FAMILY FELLODISTOMATIDAE Nicoll, 1913

Tergestia pectinata (Linton, 1905) Manter, 1940
Synonyms: Distomum pectinatum Linton, 1905; *Theledra pectinata* (Linton) Linton, 1910
Hosts: Bairdiella chrysura; Caranx crysos; C. hippos
Site: intestine
Localities: Alligator Harbor; Dog Island Reef

Steringotrema corpulentum (Linton, 1905) Manter, 1931
Synonym: Distomum corpulentum Linton, 1905
Host: Lagodon rhomboides
Site: intestine
Locality: Alligator Harbor

FAMILY HAPLOSPLANCHNIDAE Poche, 1925

Schikhobalotrema acutum (Linton, 1910) Skrjabin and Guschanskaja, 1955**
Synonyms: Deradena acuta Linton, 1910; *Haplosplanchnus acutus* (Linton) Manter, 1937
Host: Strongylura marina
Site: intestine
Locality: Alligator Harbor
Deposited specimen: U.S.N.M. No. 60081

Schikhobalotrema sp.
Host: Mugil cephalus
Site: intestine
Locality: Alligator Harbor
The four specimens found are not favorable for study. They probably represent a new species of haplosplanchnid.

FAMILY GORGODERIDAE Looss, 1901

Nagmia floridensis Markell, 1953
Host: Dasyatis sabina
Site: body cavity
Locality: Alligator Harbor

A great deal of confusion exists regarding generic features in the Anaporrhutinae, and the validity of the genus *Nagmia* has been questioned by Johnston (1934) and others. *Nagmia floridensis* was described from a single specimen, and the vitellaria were reported as partly medial and partly ventral to the ceca. Our material shows variation in their position, with the majority of the worms having vitellaria partly extracecal and partly overlapping the ceca ventrally. Two immature specimens show clearly the excretory vesicle as Y-shaped; in adults, the unbranched stem is seen but its arms are concealed.

FAMILY OPECOELIDAE Ozaki, 1925

Opecoeloides fimbriatus (Linton, 1934) Sogandares-Bernal and Hutton, 1959
Synonym: Cymbephallus fimbriatus Linton, 1934
*Hosts: Bairdiella chrysura: Menticirrhus americanus; *M. focaliger; M. littoralis: Micropogon undulatus: Sciaenops ocellata*
Site: intestine
Localities: Alligator Harbor; Mud Cove; St. George Island
The original description by Linton is inadequate and the species has been redescribed

by Sogandares-Bernal and Hutton (1959b), and by Kruse (1959) from Linton's type specimen and additional ones collected from Apalachee Bay. The single specimen from *Micropogon undulatus* has a smaller sucker ratio (1:1.17) and fewer acetabular papillae (exact number cannot be determined). On the basis of these features, it should perhaps be referred to *O. polynemi* Von Wicklen, 1946. Sogandares-Bernal and Hutton (1959c) questioned the validity of *O. polynemi;* in sucker ratio (1:1.25) it comes close to the lower limit found in some of our specimens from the other hosts (range 1:1.3-1.8). The papillae on the acetabulum may be retracted and thus may be indiscernible; Kruse (1959) reported "four lobes each having from five to nine papillae" and Sogandares-Bernal and Hutton (1959b, Fig. 13) show 6, 6, 6, and 8 papillae per lobe. No such variation, however, is reported by Von Wicklen in her 10 specimens of *O. polynemi.*

Genitocotyle **cablei** n.sp.

Figure 1

Host: Ancylopsetta quadrocellata
Site: intestine
Locality: Dog Island Reef
Holotype: U.S.N.M. No. 60082

Description and measurements based on two specimens. Body elongated, 2.70-2.93 long, 0.567-0.600 wide. Oral sucker 0.165-0.185 in diameter; ventral sucker in anterior third of body, pedunculate, 0.268-0.294 in diameter, with three or four small papillae on anterior and posterior margins; sucker ratio 1:1.54-1.62. Accessory "sucker" pit-like and without a limiting membrane, surrounded by a few cells, about half-way between pharynx and ventral sucker. Prepharynx short; pharynx large, 0.155 in diameter; esophagus slender, 0.294-0.360 long; cecal bifurcation at level of anterior margin of ventral sucker; ceca ending blindly near posterior end of body. Testes two, smooth, tandem, close together, 0.232-0.309 in diameter. Cirrus sac absent; seminal vesicle tubular, reaching posteriorly halfway between ventral sucker and ovary; ejaculatory duct very long and slender, extending from posterior end of acetabulum to level of posterior margin of pharynx. Ovary entire, pretesticular, 0.155-0.180 in diameter; seminal receptacle absent; uterus preovarian; eggs 56-64 by 31-36 microns. Genital pore ventral, slightly sinistral, near level of posterior margin of pharynx. Vitelline follicles extending from level of posterior margin of ventral sucker to posterior end of body, confluent in posttesticular space. Excretory vesicle tubular, extending to ovary.

This species is referred to the genus *Genitocotyle* Park, 1937, on the basis of an accessory sucker (preacetabular pit) and blind ceca, conditions determined on live material as well as on frontal sections of one of the two specimens. Unlike other members in the genus, this species has acetabular papillae. We do not feel, however, that a new genus is justified on that basis.

Genitocotyle **cablei** differs from the other three species in the genus in having acetabular papillae. It further differs from *G. acirra* Park, 1937, in the position of the genital pore, in lacking a limiting membrane around the accessory sucker, and in having smaller eggs; from *G. atlantica* Manter, 1947, chiefly in extent of vitellaria and shape of the gonads; and from *G. heterostichi* Montgomery, 1957, in extent of vitellaria, position of the genital pore and seminal vesicle, and in lacking a limiting membrane around the accessory sucker. Neither the whole mount nor the frontal sections in our limited material show a true seminal receptacle. Such a structure is also reported as absent in *G. heterostichi* but present in the other two species. This structure is of generic value, at least in some opecoelids.

The species is named in honor of Professor R. M. Cable of Purdue University, Lafayette, Indiana, in recognition of his contributions to the knowledge of the Trematoda.

FAMILY LEPOCREADIIDAE Nicoll, 1934

Lepocreadium **brevoortiae** n.sp.

Figure 2

Host: Brevoortia patronus
Site: intestine
Localities: Alligator Harbor; Mud Cove
Holotype: U.S.N.M. No. 60083

Description and measurements based on 20 specimens. Body elongated, tapering anteriorly, rounded posteriorly, 0.850-1.140 long, 0.260-0.390 wide. Cuticle spinose; eye spot pigments diffuse. Oral sucker subterminal, 0.078-0.108 in diameter; ventral sucker in mid-third of body, sometimes equa-

torial, 0.072-0.090 in diameter; sucker ratio 1:0.85-1.00. Prepharynx absent or very short; pharynx massive, sometimes larger than oral sucker, 0.080-0.096 in diameter; esophagus about half to one and a half length of pharynx; cecal bifurcation about midway between suckers; ceca extending to level of posterior vitelline follicles. Testes two, entire, tandem, contiguous, 0.072-0.150 in diameter. Cirrus sac long, about 1/4 body length, sometimes reaching ovarian zone, containing subspherical internal seminal vesicle, large pars prostatica, and long muscular spiny cirrus; spines of cirrus minute, sometimes partially lost; external seminal vesicle saccate, often overlapping ovary dorsally. Ovary triangular in shape, contiguous with anterior testis, 0.060-0.096 in diameter; seminal receptacle postovarian; uterus preovarian. Eggs 60-66 by 31-41 microns. Vitelline follicles extending from level of intestinal bifurcation to near posterior end of body, confluent in posttesticular space. Genital atrium small; genital pore preacetabular, sinistral. Excretory vesicle tubular, anterior extent not determined; excretory pore terminal.

The combination of a massive pharynx any spiny cirrus distinguish *Lepocreadium* **brevoortiae** from all the other 21 species in the genus. The massive pharynx is a constant feature not due to excessive flattening and was seen in the live material obtained from 13 fish from two localities. A large pharynx is described for *L. incisum* Hanson, 1955 and *L. clavatum* (Ozaki, 1932); Yamaguti, 1938 but both species lack a spiny cirrus, the cirrus sac does not extend posterior to the ventral sucker, and the ovary and testes are lobed. *L. pyriforme* (Linton, 1900) Linton, 1940 has a spiny cirrus. Sogandares-Bernal & Hutton (1960) discussed this species and concluded that there are several species involved in Linton's descriptions. Nahhas & Cable (1964) accepted as this species only individuals that are similar to Figure 47 (Linton, 1940) or Figure 9 (Sogandares-Bernal & Hutton, 1960). On this basis, *L.* **brevoortiae** would differ from *L. pyriforme* by having a larger pharynx, shorter prepharynx, and more anterior extent of the vitellaria.

Lepocreadium floridanus Sogandares-Bernal and Hutton, 1959

Host: Lagodon rhomboides
Site: intestine
Locality: Alligator Harbor

Three specimens are in close agreement with the description of Sogandares-Bernal and Hutton (1959a) except for a somewhat oval body shape rather than an elongated one. In one specimen, the testes were slightly oblique. Egg size was not given in the original description of the species. In our material the range is 54-72 by 26-38 microns.

Another group of more elongated worms with vitellaria extending only to the acetabulum, was found in the same host species. They were first thought to be *Lepocreadium pyriforme* (Linton, 1900) as limited in the discussion of the previous species. However, the cirrus lacks spines and for the time being the trematodes are considered as younger forms of *Lepocreadium floridanus*.

Opechona gracilis (Linton, 1910) Manter, 1947**

Figure 3

Synonym: Prodistomum gracile Linton, 1910; nec *Opechona gracilis* (Manter, 1931) Ward & Fillingham, 1934
*Host: *Peprilus alepidotus*
Site: intestine
Locality: Mud Cove
Deposited specimen: U.S.N.M. No. 60084

The present material is referred to this species on the basis of shape of the ovary, extent of vitellaria and excretory vesicle, sucker ratio and other measurements. Our specimens differ, however, in egg size and in having a definite prepharynx varying in length from about one half to one and a half the length of the pharynx. The eggs in our material are collapsed and measure 72-82 by 30-37 as compared with 61-64 by 37-47 microns (Manter, 1947).

Apocreadium mexicanum Manter, 1937**

Host: Monacanthus hispidus
Site: intestine
Locality: Alligator Harbor

This species was first described by Manter from the Pacific Coast. Siddiqi and Cable (1960) reported it from Puerto Rico but noted "slight differences in sucker ratio, width of eggs, and length of posttesticular

space." Nahhas and Cable (1964) found this species in *Monacanthus hispidus* in Jamaica and noted that their specimens were "more like those of Siddiqi and Cable (1960) . . ." and that "the posttesticular space usually is less than half as long as the body but sometimes the two regions are about equal in length." Eggs of the Florida material measure 70-84 by 30-48 microns compared with 63-71 by 42-45 microns for the Jamaican material. Manter (1937) gave an egg size range of 61-67 by 31-34 microns.

Homalometron pallidum Stafford, 1904
Host: Leiostomus xanthurus
Site: intestine
Locality: Alligator Harbor

Multitestis inconstans (Linton, 1905) Manter, 1931**
Synonym: Distoma inconstans Linton, 1905
Host: Chaetodipterus faber
Site: intestine
Locality: Alligator Harbor
Deposited specimen: U.S.N.M. No. 60085

Diploproctodaeum plicitum (Linton, 1928) Sogandares-Bernal & Hutton, 1958
Synonyms: Distomum sp. of Linton, 1898 and 1905; *Psilostomum plicitum* Linton, 1928; *Bianium concavum* Stunkard, 1930; *B. adplicatum* Manter, 1940; *B. plicitum* (Linton) Stunkard, 1931
Host: Chilomycterus schoepfi
Site: intestine
Locality: Alligator Harbor

Dermadena lactophrysi Manter, 1946**
Synonym: Distomum lamelliforme Linton, 1907 in part
Host: Lactophrys quadricornis
Site: intestine
Locality: Alligator Harbor
Deposited specimen: U.S.N.M. No. 60086

FAMILY CRYPTOGONIMIDAE Ciurea, 1933

Siphodera vinaledwardsii (Linton, 1899) Linton, 1910
Synonym: Monostomum vinaledwardsii Linton, 1899
Host: Opsanus beta
Site: intestine
Locality: Alligator Harbor

Metadena adglobosa Manter, 1947**
*Host: *Paralichthys albigutta*
Site: ceca
Locality: Alligator Harbor

Two specimens, one mature but damaged, and one immature, were recovered along with a number of individuals of *Bucephaloides bennetti.* The egg size and that of the oral sucker relative to body width are characteristic of this species. This species has hitherto been known only from snappers of the genus *Lutjanus.*

Pseudoacanthostomum **floridensis** n.sp.
Figure 4

Synonym: Pseudoacanthostomum panamensis of Corkum, 1959, nec Caballero et al., 1953
Host: Galeichthys felis
Site: intestine
Locality: Alligator Harbor
Holotype: U.S.N.M. No. 60087

Description and measurements based on two specimens, one sectioned frontally. Body elongated, 2.63-3.00 long, 0.489-0.750 wide. Cuticle with spines extending to level of posterior testis; eye spot pigments present. Oral sucker like an inverted bell, 0.180-0.294 long, 0.309-0.330 in greatest width; mouth surrounded by single row of 28 perioral spines measuring 42-60 by 18-24 microns; ventral sucker in anterior third of body, 0.118-0.155 long, 0.155-0.170 wide; sucker ratio 1:0.54. Prepharynx contracted in holotype, longer than pharynx in paratype; pharynx 0.129-0.206 in diameter; esophagus very short; ceca extending to posterior end of body, and joining excretory vesicle by two narrow ducts a short distance anterior to excretory pore. Testes two, ovoid or rhomboid, tandem, well separated, 0.283-0.309 long, 0.180-0.283 wide; seminal vesicle tubular, sinuous, extending posteriorly to about halfway between ventral sucker and ovary; prostate cells free in parenchyma. Ovary trilobed, about midway between ventral sucker and anterior testis, 0.232-0.260 long, 0.298-0.309 wide; seminal receptacle spherical, preovarian; uterine coils extending to near posterior tips of ceca. Genital pore median, immediately preacetabular; gonotyl as large as ventral sucker, the two sometimes overlapping. Eggs 20-25 by 11-14 microns. Vitelline follicles small, sometimes granular, extending from anterior testis laterally and

dorsally some distance anterior to ventral sucker but not reaching intestinal bifurcation. Excretory vesicle Y-shaped, wide arms extending from near posterior testis to mid-level of pharynx; pore terminal.

This is the second species in the genus *Pseudoacanthostomum*. *P.* **floridensis** differs from *P. panamensis* Caballero, Bravo H. and Grocott, 1953 from *Galeichthys seemani* from the Pacific Coast in the number of perioral spines (28 compared with 26), greater extent of the vitellaria, and the presence of a uroproct. This last feature was suspected in the live material and confirmed by frontal sectioning of the paratype.

Corkum (1959) reported a single specimen with 28 perioral spines as *P. panamensis* from *Galeichthys felis*. We have borrowed this specimen and found it to agree with our material also in the distribution of the vitellaria. The connections of the ceca with the stem of the vesicle could not be determined as they were concealed by the uterine coils. Figure 5 is a tracing of a photomicrograph of Corkum's material.

FAMILY ACANTHOCOLPIDAE Lűhe, 1909

Stephanostomum ditrematis (Yamaguti, 1939) Manter, 1947

Synonyms: Echinostephanus ditrematis Yamaguti, 1939; *Stephanostomum longisomum* Manter, 1940; *Stephanostomum filiforme* Linton, 1940

Host: Caranx hippos
Site: intestine
Locality: Alligator Harbor

Stephanostomum interruptum Sparks & Thatcher, 1958

Hosts: Bairdiella chrysura: Cynoscion arenarius; C. nebulosus
Site: intestine
Locality: Alligator Harbor

Stephanostomum megacephalum Manter, 1940

Host: Caranx hippos
Site: intestine
Locality: Alligator Harbor

Stephanostomum sentum (Linton, 1910) Manter, 1947**

Synonym: Stephanochasmus sentus Linton, 1910

*Host: *Menticirrus americanus*
Site: intestine
Locality: Alligator Harbor

Stephanostomum metacercaria

Host: Monacanthus hispidus
Site: wall of the heart
Locality: Alligator Harbor

A single specimen, with 34 perioral spines and an oral sucker smaller than the ventral sucker, was found encysted on the wall of the heart.

Pleorchis americanus Lűhe, 1906

Synonyms: Distomum polyorchis Linton, 1901 nec Stossich, 1888; *Distoma molle* (Leidy, 1856) Stiles & Hassall, 1894; *Pleorchis mollis* (Leidy, 1856) Stiles, 1896; *Pleorchis lintoni* Yamaguti, 1938; *Polyorchis molle* (Leidy, 1856) Mont., 1896

Hosts: Cynoscion arenarius; C. nebulosus
Site: intestine
Localities: Alligator Harbor; Dog Island Reef; St. Marks

FAMILY HEMIURIDAE Lűhe, 1901

Aponurus laguncula Looss, 1907

*Hosts: *Centropristis melanus; *Lagocephalus laevigatus; *Paralichthys albigutta*
Site: stomach
Localities: Alligator Harbor; Dog Island Reef; St. George Island

Fourteen worms collected from three fishes are 0.541-1.275 long, 0.138-0.335 wide. We first thought that three worms from *Lagocephalus laevigatus* represented a different species because they were larger (1.200-1.275 by 0.319-0.335) than those from the other two hosts (0.541-0.849 by 0.138-0.180) and their eggs were slightly thicker-shelled, narrower at one end, and measure 30-32 by 17-18 compared with 26-31 by 14-17 microns. Egg measurements overlap, and proportions of organs are the same, however. In body size and egg shape, the three larger trematodes are similar to *A. trachinoti* Manter, 1940 but this species has smaller eggs (25 by 10 microns).

Aponurus elongatus Siddiqi & Cable, 1960**

Host: Chaetodipterus faber
Site: stomach
Localities: Alligator Harbor; Dog Island Reef

Deposited specimen: U.S.N.M. No. 60088

Three specimens found in this study agree closely with the description of Siddiqi & Cable (1960) but differ in having slightly

larger eggs (28-35 by 16-18 compared with 26-29 by 13-16 microns). Siddiqi and Cable did not distinguish their species from others in the genus. It is most similar to *A. lagunculа* but differs in sucker ratio (1:2.5 compared to 1:1.7-2.1) and in having a more elongate body, more anterior ventral sucker, a greater postovarian space, and vitellaria that are longer than wide. *A. elongatus* is known only from *Chaetodipterus faber* and has been reported from Puerto Rico, Jamaica, and now from Apalachee Bay.

Lecithaster confusus Odhner, 1905**
Synonym: Distomum bothryophoron Olsson of Linton, 1899
*Hosts: *Brevoortia patronus; *Lagodon rhomboides*
Site: intestine
Locality: Alligator Harbor

Parahemiurus merus (Linton, 1910) Woolcock, 1935
Synonyms: Hemiurus merus Linton, 1910; *Parahemiurus parahemiurus* Vas & Pereira, 1930; *P. platichthyi* Lloyd, 1938; *P. atherinae* Yamaguti, 1938; *P. harengulae* Yamaguti, 1938
*Hosts: Brevoortia patronus; Cynoscion nebulosus; *Lagodon rhomboides*
Site: stomach
Locality: Alligator Harbor

Sterrhurus monticelli (Linton, 1898) Linton, 1910
Synonym: Distomum monticelli Linton, 1898
Host: Pomatomus saltatrix
Site: stomach
Locality: Dog Island Reef

Sterrhurus musculus Looss, 1907
Synonyms: Sterrhurus laeve (Linton) of Manter, 1931; *Sterrhurus floridensis* Manter, 1934 in part
*Hosts: *Ancylopsetta quadrocellata; *Anguilla rostrata; *Bairdiella chrysura; *Centropristis melanus; *Diplectrum formosum; *Leiostomus xanthurus; Menticirrhus americanus; *Micropogon undulatus; *Ogcocephalus radiatus; *Ophidion welshi; *Opsanus beta; *Orthopristis chrysopterus; *Paralichthys albigutta; *Syacium papillosum; Synodus foetens; *Urophycis floridanus*
Site: stomach
Localities: Alligator Harbor; Dog Island Reef; St. George Island

Lecithochirium parvum Manter, 1947
Synonym: Sterrhurus floridanus Manter, 1934 in part
*Hosts: *Leiostomus xanthurus; *Micropogon undulatus; *Paralichthys albigutta*
Site: stomach
Locality: Alligator Harbor

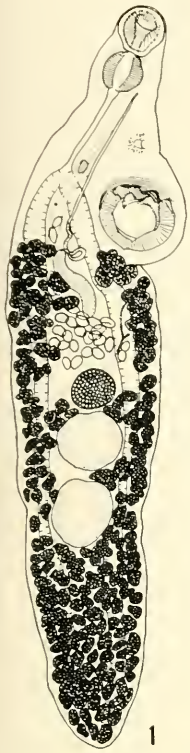
Lechithochirium microstomum Chandler, 1935
Synonym: Lecithochirium sinaloense Bravo-Hollis, 1956
*Hosts: *Anguilla rostrata; Trichiurus lepturus*
Site: stomach
Localities: Alligator Harbor; Mud Cove

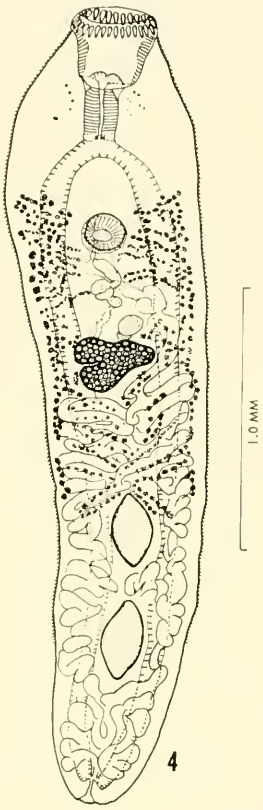
Lecithochirium texanum (Chandler, 1941) Manter, 1947
Synonym: Sterrhurus texanus Chandler, 1941
*Host: *Selene vomer*
Site: stomach
Locality: Alligator Harbor

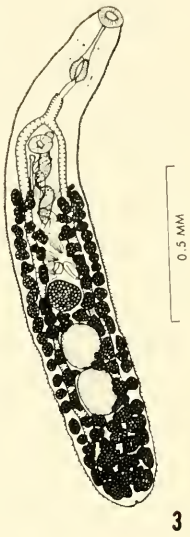
Lecithochirium mecosaccum Manter, 1947**
Figure 6
*Hosts: *Sciaenops ocellata; Synodus foetens*
Site: stomach
Locality: Alligator Harbor

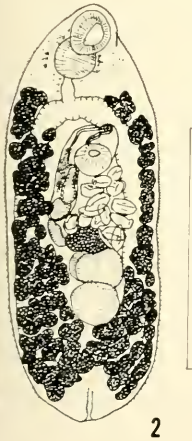
The main distinguishing features of *Lecithochirium mecosaccum* are the broad vitelline lobes, the large sinus sac and ejaculatory vesicle, and a long muscular hermaphroditic duct. The preacetabular pit, described as indistinct and nonglandular, was not observed in specimens from *Synodus foetens* but was evident in some of the specimens from *Sciaenops ocellata.* The genital pore is a slit-like opening usually just posterior to the pharynx but may be more posterior due to contraction of the muscular hermaphroditic duct.

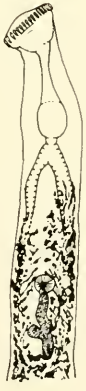
Lecithocladium excisum (Rudolphi, 1819) Lühe, 1901**
Synonyms: Lecithocladium excisiforme Cohn, 1903; *L. gulosum* (Linton, 1899) Looss, 1907; *L. cristatum* (Rudolphi, 1819) Looss, 1907; *L. crenatum* (Molin, 1859) Looss, 1907
*Hosts: *Peprilus alepidotus; Poronotus triacanthus*
Site: stomach











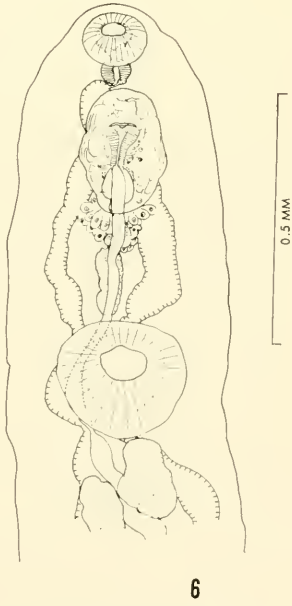


Figure 1. *Genitocotyle cablei*, holotype, ventral view. **Figure 2.** *Lepocreadium brevoortiae*, holotype, ventral view. **Figure 3.** *Opecbona gracilis*, ventral view. **Figure 4.** *Pseudoacanthostomum floridensis*, holotype, ventral view. **Figure 5.** Same, tracing of a photograph of Corkum's specimen showing mainly forebody. **Figure 6.** *Lecithochirium mecosaccum*, ventral view, from *Synodus foetens*.

Localities: Alligator Harbor; St. George Island
Deposited specimen: U.S.N.M. No. 60089

Stomachicola sp.
Host: Diplectrum formosum
Site: attached to ovary
Locality: St. George Island

Tubulovesicula sp.
Hosts: Cynoscion arenarius; C. nebulosus
Site: beneath ovarian membrane and in body wall muscles
Locality: Alligator Harbor

The worms were found on several occasions by the second author. Some contained eggs although the majority were immature. No description of the species will be given at the present since the majority of the worms are not in condition favorable for description.

FAMILY SCLERODISTOMIDAE Dollfus, 1932

Sclerodistomum sphoeroidis Manter, 1947
Host: Chilomycterus schoepfi
Site: stomach
Locality: Alligator Harbor

V. Summary

Forty-eight species of Digenea are reported from 43 species of fishes from Apalachee Bay, Florida. Three new species are described: *Genitocotyle* **cablei,** (Opecoelidae); *Lepocreadium* **brevoortiae,** (Lepocreadiidae) and *Pseudoacanthostomum* **floridensis,** (Cryptogonimidae). Fourteen new locality records bring to 109 the species of Digenea known from Tampa Bay and the northern Gulf: 27 species from the Texas coast, 50 from Louisiana, 16 from Mississippi, 31 from Tampa and Boca Ciega Bays, and 48 from Apalachee Bay..

VI. Alphabetical Host-Parasite List

Following each host species is the number, in parentheses, of individuals examined.

Ancylopsetta quadrocellata Gill ocellated flounder (1)
Genitocotyle cablei
Sterrhurus musculus
Anguilla rostrata (LeSueur), American eel (2)
Lecithochirium microstomum
Sterrhurus musculus
Bairdiella chrysura (Lacépède), silver perch (18)
Bucephaloides caecorum
Tergestia pectinata
Opecoeloides fimbriatus
Stephanostomum interruptum
Sterrhurus musculus
Brevoortia patronus Goode, largescale menhaden (24)
Lepocreadium brevoortiae
Lecithaster confusus
Parahemiurus merus
Caranx crysos (Mitchill), blue runner (5)
Bucephalus varicus
Tergestia pectinata
Caranx hippos (Linnaeus), Crevalle jack (3)
Bucephalus varicus
Tergestia pectinata
Stephanostomum ditrematis
Stephanostomum megacephalum
Centropristis melanus Ginsburg, Southern sea bass (10)
Aponurus laguncula
Sterrhurus musculus
Chaetodipterus faber (Broussonet), Atlantic spadefish (9)
Multitestis inconstans
Aponurus elongatus
Chilomycterus schoepfi (Walbaum), striped burrfish (3)
Diploproctodaeum plicitum
Sclerodistomum sphoeroidis
Cynoscion arenarius Ginsburg, sand sea trout (5)
Cardicola laruei
Pleorchis americanus
Stephanostomum interruptum
Tubulovesicula sp.
Cynoscion nebulosus (Cuvier), spotted sea trout (21)
Cardicola laruei
Pleorchis americanus
Stephanostomum interruptum
Parahemiurus merus
Tubulovesicula sp.
Dasyatis sabina (LeSueur), Atlantic stingray (1)
Nagmia floridensis
Diplectrum formosum (Linnaeus), sand perch (3)
Sterrhurus musculus
Stomachicola sp.
Galeichthys felis (Linnaeus), sea catfish (16)
Pseudoacanthostomum floridensis
Lactophrys quadricornis (Linnaeus), cowfish (2)
Dermadena lactophrysi
Lagocephalus laevigatus (Linnaeus), smooth puffer (1)
Aponurus laguncula
Lagodon rhomboides (Linnaeus), pinfish (29)
Steringotrema corpulentum
Lepocreadium floridanus
Lecithaster confusus
Parahemiurus merus
Leiostomus xanthurus Lacépède, spot (8)
Homalometron pallidum
Lecithochirium parvum
Sterrhurus musculus
Menticirrhus americanus (Linnaeus), Southern kingfish (1)
Opecoeloides fimbriatus
Stephanostomum sentum
Sterrhurus musculus
Menticirrhus focaliger Ginsburg, minkfish (1)
Opecoeloides fimbriatus
Menticirrhus littoralis (Holbrook), Gulf kingfish (1)
Opecoeloides fimbriatus

Micropogon undulatus (Linnaeus), Atlantic croaker (12)
Opecoeloides fimbriatus
Lecithochirium parvum
Sterrhurus musculus
Monacanthus hispidus (Linnaeus), planehead filefish (9)
Apocreadium mexicanum
Stephanostomum metacercaria
Mugil cephalus Linnaeus, striped mullet (4)
Schikhobalotrema sp.
Mycteroperca bonaci (Poey), black grouper (1)
Prosorhynchus atlanticus
Ogcocephalus radiatus (Mitchill), polka-dot batfish (2)
Sterrhurus musculus
Ophidion welshi (Nichols and Breder), crested cusk-eel (5)
Sterrhurus musculus
Opsanus beta (Goode and Bean), Gulf toadfish (8)
Siphodera vinaledwardsii
Sterrhurus musculus
Orthopristis chrysopterus (Linnaeus), pigfish (12)
Sterrhurus musculus
Paralichthys albigutta Jordan and Gilbert, Gulf flounder (9)
Bucephaloides bennetti
Metadena adglobosa
Aponurus laguncula
Lecithochirium parvum
Sterrhurus musculus
Peprilus alepidotus (Linnaeus), Southern harvestfish (3)
Opechona gracilis
Lecithocladium excisum
Pomatomus saltatrix (Linnaeus), bluefish (3)
Bucephaloides arcuatus
Sterrhurus monticelli
Poronotus triacanthus (Peck), butterfish (1)
Lecithocladium excisum
Sciaenops ocellata (Linnaeus), red drum (2)
Bucephaloides megacirrus
Opecoeloides fimbriatus
Lecithochirium mecosaccum
Scoliodon terrae-novae (Richardson) Atlantic sharpnose shark (1)
Sclachohemecus olsoni
Scomberomorus maculatus (Mitchill), Spanish mackerel (1)
Bucephaloides arcuatus
Rhipidocotyle baculum
Selene vomer (Linnaeus), lookdown (1)
Lecithochirium texanum
Strongylura marina (Walbaum), Atlantic needlefish (3)
Rhipidocotyle transversale
Schikhobalotrema acutum
Strongylura notata (Poey), redfin needlefish (2)
Rhipidocotyle transversale
Syacium papillosum (Linnaeus), dusky flounder (1)
Sterrhurus musculus
Synodus foetens (Linnaeus), inshore lizardfish (2)
Lecithochirium mecosaccum
Sterrhurus musculus
Trichiurus lepturus Linnaeus, Atlantic cutlassfish (1)
Lecithochirium microstomum
Urophycis floridanus (Bean and Dresel), Southern hake (2)
Sterrhurus musculus

VII. List of Fishes Negative for Trematodes

The numbers in parentheses following common names of fishes represent numbers of individuals examined.

Anchoa hepsetus (Linnaeus), striped anchovy (2)
Archosargus probatocephalus (Walbaum), sheepshead (1)
Bagre marinus (Mitchill), gafftopsail catfish (1)
Cyprinodon variegatus Lacépède, sheepshead minnow (1)
Dorosoma cepedianum (LeSueur), gizzard shad (2)
Echeneis naucrates Linnaeus, sharksucker (1)
Elops saurus Linnaeus, ladyfish (2)
Etropus crossotus Jordan and Gilbert, fringed flounder (1)
Eucinostomus argenteus Baird and Girard, spotfin mojarra (8)
Eucinostomus gula (Quoy and Gaimard), silver jenny (1)
Fundulus similis (Baird and Girard), longnose killifish (9)
Haemulon sciurus (Shaw), blue striped grunt (1)
Larimus fasciatus Holbrook, banded drum (1)
Lutjanus griseus (Linnaeus), gray snapper (1)
Menidia beryllina (Cope), tidewater silverside (3)
Mugil curema Valenciennes, white mullet (2)
Paralichthys lethostigma Jordan and Gilbert, Southern flounder (1)
Porichthys porosissimus (Cuvier), Atlantic midshipman (3)
Prionotus tribulus Cuvier, bighead searobin (1)
Trinectes maculatus (Bloch and Schneider), hogchoker (4)

VIII. References Cited

Corkum, K. C. 1959. Some trematode parasites of fishes from the Mississippi Gulf coast. *Proc. Louisiana Acad. Sci.* 22: 17-29.

Johnston, T. H. 1934. Some Australian anaporrhutine trematodes. *Trans. Roy. Soc. South Australia.* 58: 139-148.

Kruse, D. N. 1959. Parasites of the commercial shrimps, *Penaeus aztecus* Ives, *P. duorarum* Burkenroad and *P. setiferus* (Linnaeus). *Tulane Stud. Zool.* 7: 123-144.

Linton, E. 1940. Trematodes from fishes mainly from the Woods Hole region, Massachusetts. *Proc. U. S. Natl. Mus.* 88: 1-172.

Manter, H. W. 1937. A new genus of distomes (Trematoda) with lymphatic vessels. *Hancock Pac. Exp.* 2: 11-22, pl.

. 1947. Digenetic trematodes of marine fishes of Tortugas, Florida. *Amer. Midland Nat.* 38: 257-416.

. 1954. Trematoda of the Gulf of Mexico. In 'Gulf of Mexico, its origin, waters, and marine life.' *Fishery*

Bull. (89) *of the U. S. Fish and Wildlife Service.* 55: 335-350.

NAHHAS, F. M. and R. M. CABLE 1964. Digenetic and aspidogastrid trematodes from marine fishes of Curaçao and Jamaica. *Tulane Stud. Zool.* 11: 169-228.

RIGGIN, G. T., JR. and A. K. SPARKS 1962. A new gasterostome, *Buccephaloides megaecirrus*, from the redfish, *Sciaenops ocellata*. *Proc. Helminthol. Soc. Wash.* 29: 27-29.

SHORT, R. B. 1953. A new blood fluke, *Cardicola laruei* n.g., n.sp. (Aporocotylidae) from marine fishes. *J. Parasitol.* 39: 304-309.

_____. 1954. A new blood fluke, *Selachohemeeus olsoni*, n.g., n.sp. (Aporocotylidae) from the sharp-nosed shark, *Scoliodon terrae-novae*. *Proc. Helminthol. Soc. Wash.* 21: 78-82.

SIDDIQI, A. and R. M. CABLE 1960. Digenetic trematodes of marine fishes of Puerto Rico. *Sci. Sur. Porto Rico and the Virgin Is.* 17: 257-369.

SOGANDARES-BERNAL, F. and R. F. HUTTON 1959a. Studies on helminth parasites of the coast of Florida I. Digenetic trematodes of marine fishes from Tampa and Boca Ciega Bays with descriptions of two new species. 1. *Bull. Mar. Sci. Gulf Carib.* 9: 53-68.

_____. 1959b. Studies on helminth parasites from the coast of Florida. III. Digenetic trematodes of marine fishes from Tampa and Boca Ciega Bays. *J. Parasitol.* 45: 337-346.

_____ 1959c. Studies on helminth parasites from the coast of Florida. IV. Digenetic trematodes of marine fishes of Tampa, Boca Ciega Bays, and the Gulf of Mexico. 3. *Quart. J. Fla. Acad. Sci.* 21: 259-273.

_____ 1960. The status of some marine species of *Lepocreadium* Stossich, 1904 (Trematoda: Lepocreadiidae) from the North American Atlantic. *Lib. Hom. E. Caballero y C.* (Mexico): 275-283.

SPARKS, A. K. 1960. Some aspects of the zoogeography of the digenetic trematodes of shallow-water fishes of the Gulf of Mexico. *Lib. Hom. E. Caballero y C.* (Mexico): 285-298.

February 23, 1965

TULANE STUDIES IN ZOOLOGY

Volume 12, Number 3 June 23, 1965

HISTOLOGY, DEVELOPMENT, AND INDIVIDUAL VARIATION OF COMPLEX MUROID BACULA

ANDREW A. ARATA,
NORMAN C. NEGUS
and
MARTHA SAPP DOWNS,[1]

Department of Zoology,
Tulane University,
New Orleans, Louisiana

CONTENTS

I. INTRODUCTION 52

II. MATERIALS AND METHODS 52

III. RESULTS AND DISCUSSION 53

A. Histology 53

B. Development and individual variation 55

C. Os clitorides in muroid genera with complex bacula 61

D. Taxonomic implications 62

IV. ACKNOWLEDGEMENTS 63

V. REFERENCES CITED 64

ABSTRACT

Bacular development, morphology, and variation was studied in *Microtus*, *Ondatra*, *Sigmodon*, *Mesocricetus*, and *Rattus*.

Bacular shaft development is essentially similar in all forms in which it was studied. A synovial joint is described as present between the shaft and the distal processes of the baculum. The distal processes were observed ossified only in *Rattus*. In all other forms studied, the cartilage of these processes calcifies when sexual maturity is reached.

The total length of the baculum and the bacular index (a summation of the length times the width of the shaft and the product of the length of the median process times that of a lateral distal process) shows no correlation with known-age of 96 *Microtus montanus*, but, rather, is related to the total length of the individual. The development and absolute form of the baculum presumably is controlled in part by hormonal and genetic factors, and chronological age is not as important as physiological age in its development.

Individual variation in the baculum of *Microtus montanus* is described. The "os clitoridis" of *Mesocricetus* is not homologous to that of *Ondatra* as each

[1] Present address, Department of Zoology, University of California, Berkeley.

EDITORIAL COMMITTEE FOR THIS PAPER:

W. ROBERT EADIE, Professor of Zoology, Cornell University, Ithaca, New York

EMMET T. HOOPER, Professor of Zoology, Museum of Zoology, University of Michigan, Ann Arbor, Michigan

W. B. QUAY, Associate Professor of Zoology, University of California, Berkeley, California

bone or cartilaginous element is apparently homologous to a different part of the complex baculum.

The similarity observed in the development, histology, and general form of the baculum of *Rattus* and the cricetids studied herein, suggests that murids and cricetids represent but a single family.

I. Introduction

The baculum of many muroid rodents consists of a proximal shaft and three distal processes (Figure 1). It has been recognized for a long time (Gilbert, 1892; Tullberg, 1899), and considered characteristic of the

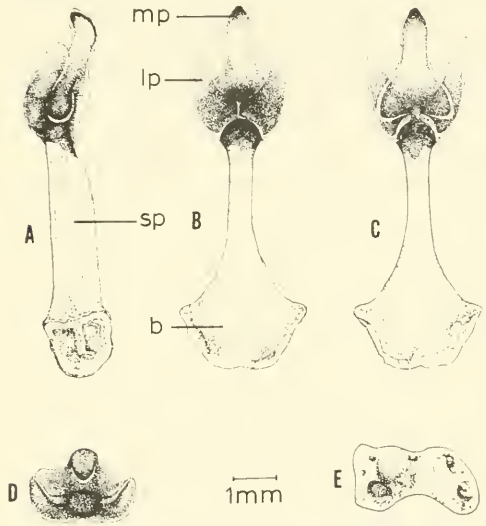


Figure 1. Views of the complex baculum of *Sigmodon hispidus*. The parts of the baculum are: median (mp) and lateral (lp) distal processes; the spine (sp) and base (b) of the shaft. The views illustrated are: A. lateral, B. dorsal (anti-urethral), C. ventral, D. distal (urethral uppermost), E. proximal (anti-urethral uppermost).

Microtinae, the Cricetini, and certain Neotropical or neotropically derived Hesperomyini (Cricetinae) and some Muridae (Hooper and Musser, 1964).

Hamilton (1946) described the baculum in numerous Microtinae, as well as in *Sigmodon* and *Oryzomys* (Cricetinae), and pointed out the similarity of the structure in such supposedly diverse groups. He also illustrated a series of bacula of *Microtus pennsylvanicus* and showed the general change in form associated with the assumed age of the animal. Callery (1951) illustrated series of bacula from a few known-age hamsters *(Mesocricetus auratus)* produced by inbreeding from a single pair of animals. Anderson (1960) figured a growth curve in which length of the bacular shaft of *Microtus ochrogaster* was plotted against total length of the animal. Elder and Shanks (1962) discussed bacular changes in a limited series of known-age muskrats *(Ondatra zibethicus)*. To our knowledge, no study is available describing changes in the morphology of the baculum in a large series of known-age animals, or considering the histology and changes occurring in the distal processes of this element.

II. Materials and Methods

This report is based on histological observations of the bacula of 6 muroid genera (Table 1), and approximately 50 locally collected hystricomorphs *(Myocastor coypus)*. One-hundred and thirty-eight *Microtus montanus* (including 97 known-age males and 21 known-age females) used in this study for growth and development data were taken from a laboratory breeding colony maintained by one of us (Negus). This colony originated from about 100 *Microtus montanus* live trapped in Jackson Hole, Wyoming. These animals were maintained

Table 1.
Muroid species and number of specimens (in parentheses) examined in this study. Supergenerie groupings follow Simpson (1945).

Superfamily Muroidea	
Family Cricetidae	
Subfamily Cricetinae	
Tribe Cricetini	
Mesocricetus auratus (males 3; females 2)	5
Tribe Hesperomyini	
Sigmodon hispidus (males 3; females 1)	4
Peromyscus gossypinus (males 4; females 2)	6
Subfamily Microtinae	
Tribe Microtini	
Ondatra zibethicus (males 5; females 3)	8
Microtus montanus (males 143; females 33)	176
Family Muridae	
Subfamily Murinae	
Rattus norvegicus (males 5; females 2)	7
Total Specimens Examined	206

as pairs in the laboratory, and fed a basic diet of rabbit chow supplemented every few days with lettuce and other greens. A constant photoperiod of 18 hours per day was maintained and room temperature was maintained by air conditioning. No inbreeding was permitted in the colony. Individuals were weaned at 15 days of age, at which time the litters were placed in separate cages, weighed, measured and sexed.

III. Results and Discussion

A. *Histology*

The bacular shaft of all forms we have examined is true bone. It consists of a laterally enlarged basal area to which the M. corpus cavernosus attaches and a spine-like distal projection (Figure 1). In all respects, the structure in cricetids is similar to that of *Rattus* (Ruth, 1934). In small species (i.e. *Microtus montanus*) and small individuals of large forms (*i.e., Sigmodon*) the shaft is formed by a single haversian system identical to that of the simple baculum of *Peromyscus* and other Nearctic cricetines (Figure 2). The spine may be composed of several haversian systems in larger forms (e.g. *Ondatra*). In cross-section the spine

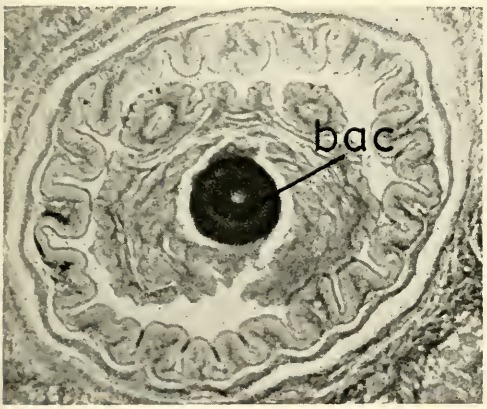


Figure 2. Cross-section of the phallus of *Peromyscus gossypinus*, illustrating the nature of the spine of the baculum (bac).

is circular, oval, or dorso-ventrally flattened. This spine is generally characteristic of the species, but much variation and overlap exists.

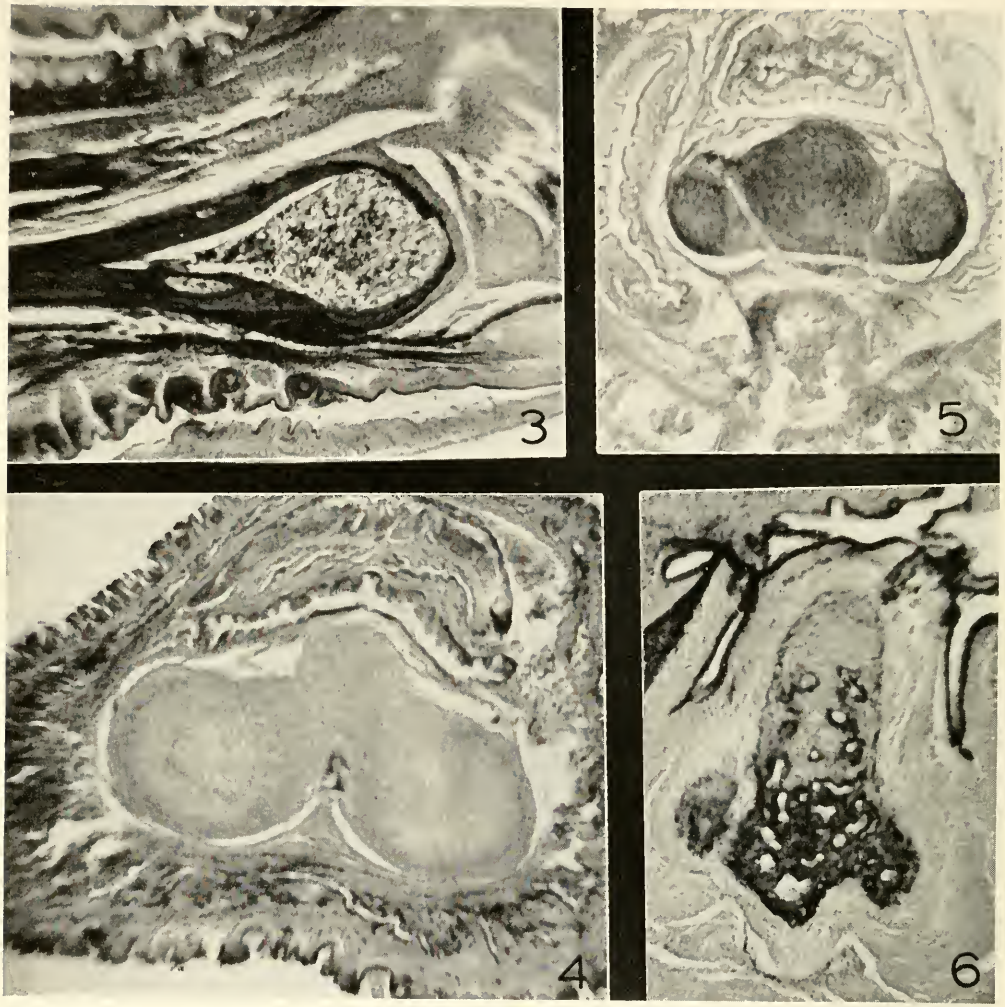
Ruth (1934) termed the bony development of the shaft of *Rattus* an endoblastemal ossification in which osteogenic cells become active in laying down osteoid substance before any marked differentiation of surrounding tissues can be observed. Although we have not sectioned pre- or neo-natal cricetids, the bony formation in one-week-old *Microtus* is similar to that described by Ruth (op. cit.). Diameter increase is by means of an active periosteum. An endosteum is seen in young animals. Maximum shaft length is achieved near breeding age.

Hemopoietic bone marrow and fatty tissue are present in the enlarged basal area of the shaft (Figure 3). Cancellous bone is present in some species. In large individuals of *Microtus,* and in most individuals of larger forms (e.g. *Ondatra*) these tissues extend into the medullary cavity of the spine for more than one-half its length.

The several elements of the complex baculum (the shaft and the distal processes) are not of the same origin or histological nature. The distal processes, often referred to as cartilage, ossifying in adults, have not been described histologically. The cartilaginous nature of these processes in young individuals has been described by many (Hamilton, 1946; Callery, 1951; Dearden, 1958; Anderson, 1960; Elder and Shanks, 1962; and others), but the subsequent "bony" development often described is usually considered to be typical endochondral ossification. In only one form (*Rattus*) have we observed this to be the case.

The "ossifications" of the distal processes of the complex cricetid baculum seen are only calcifications of either hyaline or fibrocartilage. In *Mesocricetus* (Figure 4), *Microtus* (Figure 5) and *Sigmodon,* no true ossifications were found. Only in *Rattus* (Figure 6) were true ossifications of the distal processes observed. An apparent reason for this oversight in previous work is that most studies on bacular morphology employ clearing (in KOH and glycerin) and staining (with Alizarin Red) of the whole glans penis in which the bony structure is found. Staining by Alizarin Red is not specific to bone, however, but calcium specific, and differentiation between an ossification and a calcification is not discernible with this technique.

The baculum of *Rattus* is usually considered to consist of but two osseous portions (Taylor, 1961) and although Hooper (1960) and Hooper and Musser (1964) do consider the glans penis of murines to represent the complex type, the presence of the lateral



Figures 3-6. Histological preparations of phalli. 3. Longitudinal section through the phallus of *Microtus montanus* showing hemopoietic tissue present in the enlarged basal area of the baculum. 4-6. Cross-sections through the distal regions of the phalli showing the relative sizes and nature of the distal processes. 4. *Mesocricetus auratus* 5. *Microtus montanus* 6. *Rattus norvegicus.*

distal processes is often overlooked. Whereas these structures are not as free as are those in the cricetids examined by us, their presence is obvious (Figure 6). This fusion of the lateral processes to the median may represent a condition derived from the pattern typically seen in cricetines, as some cricetines show trends in this development (Figure 7).

An unusual histological feature of the bacula studied is the presence of a synovial joint (diarthrosis) between the shaft and the distal processes (Figure 8). We have observed this in *Microtus, Ondatra, Sigmodon, Mesocricetus,* and *Rattus.* Associated with this joint, but not included in the scope of this report, are tendons and muscles in the soft tissues of the glans penis affecting the movement of the distal elements. The functional morphology and possible adaptive significance of this joint and associated structures will be reported in a later paper.

The distal processes are functionally not separate entities. They develop from cartilaginous anlagen, as three elements fused, or nearly fused, near the synovial joint. The distal processes exist essentially as a single

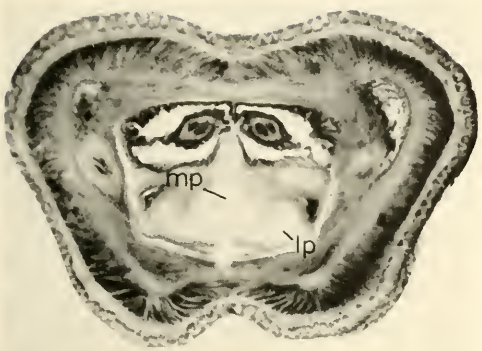


Figure 7. Cross-section of the phallus of *Sigmodon hispidus*, slightly distal to the level of the synovial joint, showing the fusion of the lateral processes (lp) with the median process (mp) near their junction with the shaft.

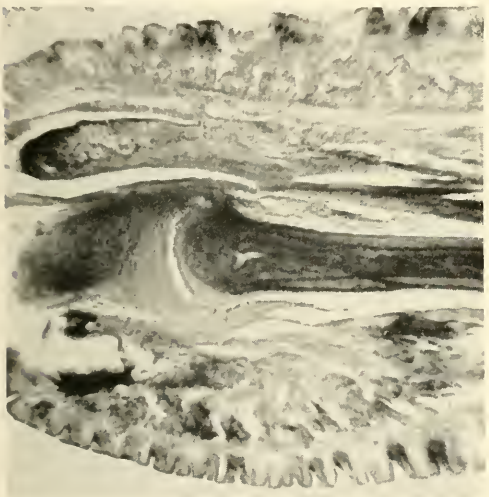


Figure 8. Longitudinal section through the phallus of *Microtus montanus* showing the synovial joint present between the distal and proximal elements of the baculum.

unit, with varying degrees of fusion, culminating in the ankylosed condition seen in adult *Rattus*.

Different degrees of calcification of the distal processes are seen in different species. It is most complete in the larger forms, or large individuals of smaller species. Large *Microtus montanus* develop sequelae. Such deposits in this region are visible in *Microtus* as anteriorly directed "spurs" (Figure 9). Extra calcification in the distal processes near the region of the synovial joint are evident in the illustrations of adult *Ondatra* (15 months of age and older) provided by Elder and Shanks (1962). If freedom of the synovial joint is essential in the reproductive activities of these forms, continued calcification may mark termination of the reproductive activity on the part of the individual. On the other hand, since most mice have short lives, such a problem may be only of academic interest.

The rod-like baculum of many Nearctic cricetines (e.g. *Peromyscus, Neotoma,* and others) is capped by a tip of hyaline cartilage which is adnate with the shaft, but

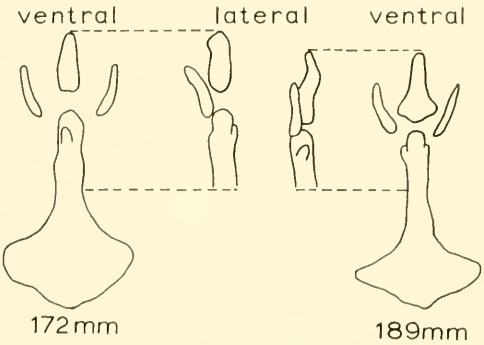


Figure 9. Excessive calcification in the bacula of large *Microtus montanus*. The "spurs" in the region of the joint between the shaft and distal processes are calcium deposits. Also note the variation in the shapes and angles of the median and lateral processes of the two bacula illustrated. The total lengths of the animals from which the bacula were obtained are given.

not joined by a synovial joint. This tip is possibly homologous with the medial distal process of the complex bacular form. Though only a small number of such bacula have been examined by us, no calcifications or ossifications in this distal tip have been noted. Hooper (1960) did report that the cartilaginous spine (i.e. tip) is one of four *Ototylomys* examined was partly osseous (calcified?).

B. *Development and Individual Variation*

The shaft of the baculum begins to develop in *Rattus* when the animal is one-day old, and within three days the definitive osseous character of the shaft is established (Ruth, 1934). The youngest *Microtus* examined by us was 7 days old (72 mm total length), and the osseous shaft of the baculum was 0.9 mm long. No basal enlargement is evident at this stage. By 15 days the basal area is well developed and cancellous. Late

development does not occur in all rodents, however. We have observed prenatal ossifications in nutria *(Myocastor coypus),* a large hystricomorph possessing a long (25 mm), simple, rod-like baculum in the adult. Such late development in the Muroidea perhaps is associated with the general altricial condition of the young.

After the first two weeks the shaft increases in length and breadth. The diameter of the spine of the shaft increases by active periosteal deposition. Calcifications are not evident in the cartilaginous distal processes until somewhat over one month (with some obvious, expected variation). Until calcifications occur, the cartilaginous limits of the distal processes are not always clearly visible in cleared and stained specimens. Calcification of the distal processes and expansion of the basal region of the shaft occur rapidly after approximately 35 days of age (Figure 10). All animals examined that were over 40 days of age had some calcification of the distal processes and only one less than 35 days of age demonstrated calcification. This rapid change in the structure of the baculum coincides with other changes of an endocrine nature occurring at the same time. Calcification of the median process appears to be more rapid (in *Microtus*) than that of the lateral elements. Generally by 50-60 days calcification of all three processes is underway.

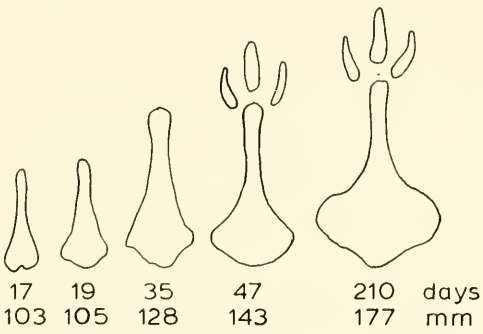


Figure 10. A selected series of bacula of *Microtus montanus* arranged by age and total length of the individual from which each was obtained, illustrating the general pattern of growth. Only calcified and true osseous elements are figured.

It is difficult to choose a single measurement that satisfactorily demonstrates the increase in size of a complex baculum. Figure 11 compares the total length of the baculum (i.e. maximum length of bone and cal-

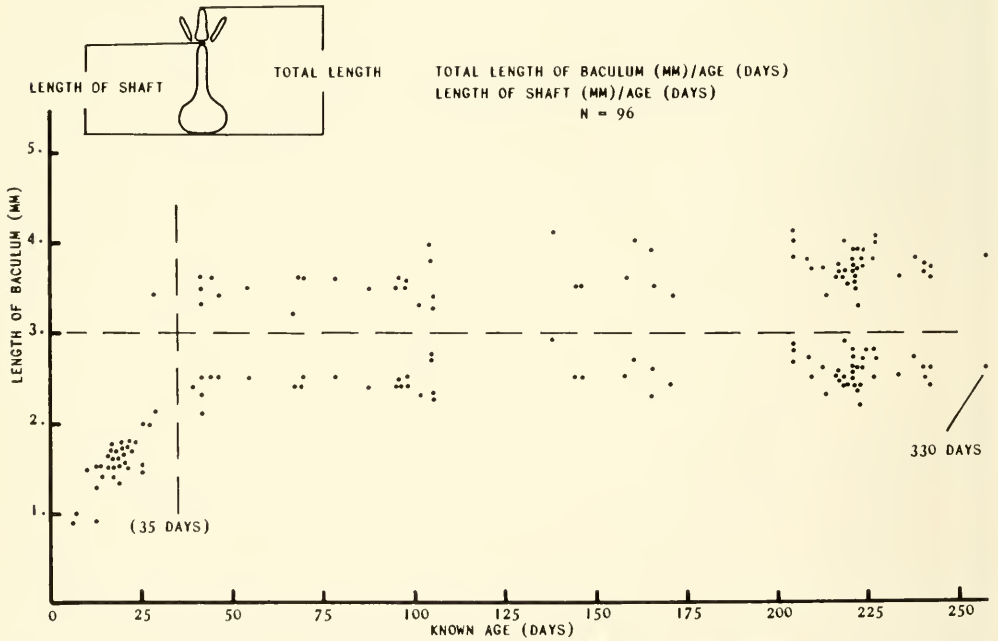


Figure 11. Comparison of the known age of 96 *Microtus montanus* to the length of the shafts of the bacula (below horizontal interrupted line) and to the total calcified length of the baculum (above horizontal interrupted line). The vertical interrupted line marks the approximate age at which the latter measurement is obtainable.

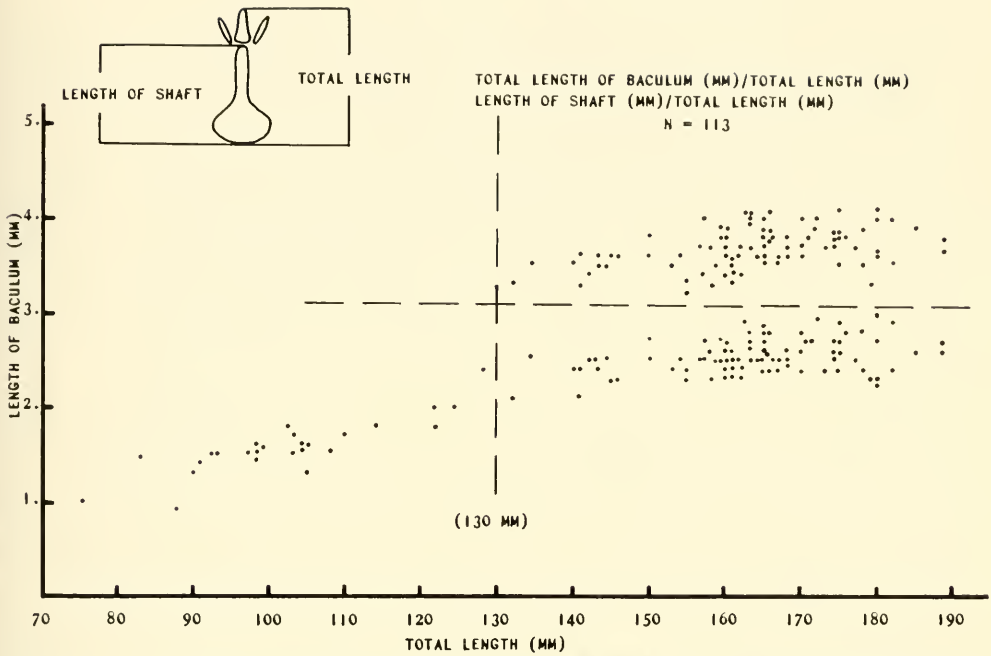


Figure 12. Comparison of the total lengths of 113 *Microtus montanus* to the lengths of the shafts of bacula (below horizontal interrupted line) and to the total calcified lengths of the bacula (above horizontal interrupted line). The vertical interrupted line marks the approximate total length at which the latter measurement is obtainable.

cified median distal process), and the length of the shaft only, against the known age of 96 *Microtus montanus*. Little or no change can be noted in either measurement after 35 days of age. The same bacular measurements are plotted against the total length of the animal (the same known age specimens plus several unknown age individuals) in Figure 12. Although a somewhat closer association is seen, the change is slight and much variation exists. Separation of individuals into age and size groups above 130 mm total length, or above 35 days of age is not possible utilizing either of these parameters (Figures 11 and 12).

Although simple lengths of the bacula do not correlate with known age or total length of the individual, subjective differences in massiveness and rugosity are evident between the bacula of young and old or small and large animals. Such impressions have, of course, been noted before. Hamilton (1946) illustrates 14 bacula of "immature", "subadult", and "mature" *Microtus pennsylvanicus*. Elder and Shanks (1962) illustrate similar changes in the bacula of twelve *Ondatra* classified as "juvenile" (5-8 months) and "adult" (15 months or more) individuals. Even though the observations concerning bacular form may be suggestive of juvenile age, *Ondatra* eight months old may be in breeding condition. The animals in their "juvenile" class (5-8 months old) were trapped in December, and born between April and July. Those born earlier in this period probably were in breeding condition during the latter part of the summer, whereas those born in July had far less chance to enter the breeding population their first year. Not all 5-8 months old *Ondatra* are juveniles, and if, as we suspect, the development of the baculum is controlled in part by hormonal factors, chronological age is not as important as physiological age. This consideration, as Elder and Shanks (1962) point out, is often ignored in taxonomic studies.

> "It seems unwise for authors comparing various species of the Microtinae to claim that only the middle, or only the lateral digital processes are calcified when only 3-4 specimens of a species have been examined. It also seems likely that disagreements as to which of the digital processes

are calcified at all in a genus such as *Phenacomys* (Dearden, 1958; Hamilton, 1946), are due to the fact that one man has examined bacula of juveniles, the other those of adults."

Of concern also is the unexplored possibility that bacular sizes and forms may differ within a population as the chronological and physiological age composition of the population changes. This could occur during a season, a year, or in a classic microtine four year cycle. It would be interesting to compare samples of bacula collected from a single population at different seasons or from year to year.

A number of attempts were made to measure the subjective impression of robustness alluded to above, that we, as well as others, note in viewing series of bacula from mice of different ages and sizes. The most successful approach is the utilization of an index, obtained by summing the product of the length times the width of the shaft and the product of the length of the median distal process times that of one (the longest) of the lateral distal processes. Plotting such an index against known age reveals considerable variation following the critical 35 day old point, indicating that, although the index tends to increase with age, the curve is not steep enough to allow separation of animals 50-75 days old from those 225 days old (Figure 13).

Plotting the same indices against total lengths of the animals reveals a closer correlation (Figure 14). The index is seen to be closely related to the size of the animal but enough individual variation is present to preclude separation of the 116 animals examined into size groups based on bacular index with any practical degree of probability.

Anderson (1960) notes that in *Microtus ochrogaster,* "sexual maturity is reached rather abruptly when the total length of most individuals is 140 to 150 millimeters." This probably corresponds to the 130 mm size we denote as critical in *M. montanus.* Anderson (op. cit.) also notes that maximum individual variation would occur in animals of this total length (140-150 mm). Our data demonstrate, however, that the greatest variability is evident in old (circa 225 days) and large (above 160 mm) voles (Figures 13 and 14).

A further indication that bacular size is

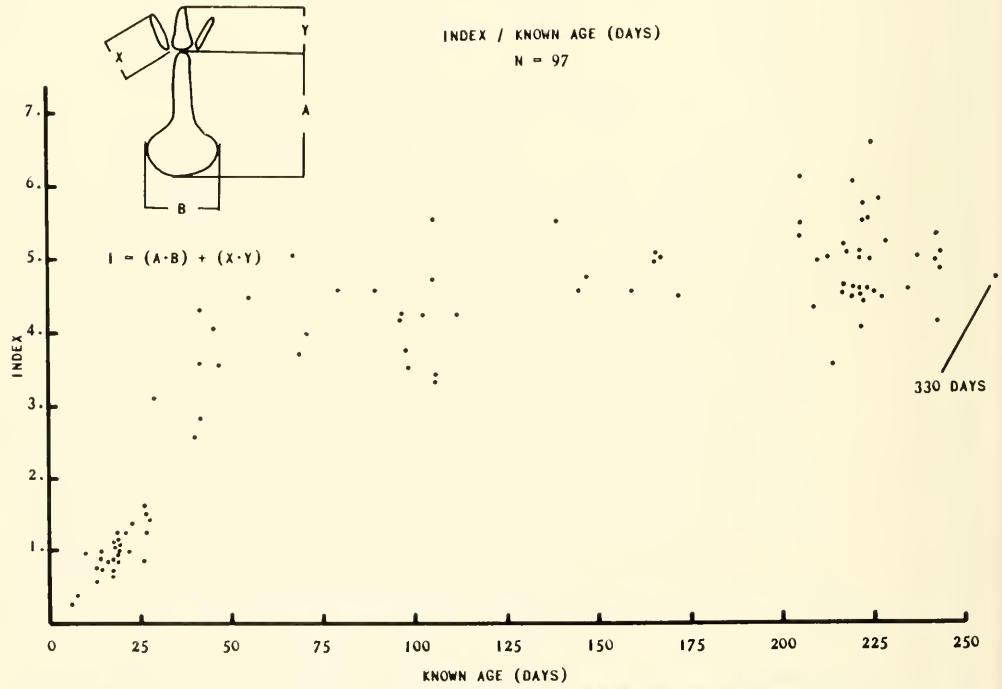


Figure 13. Comparison of the known age of 97 *Microtus montanus* to their bacular indices.

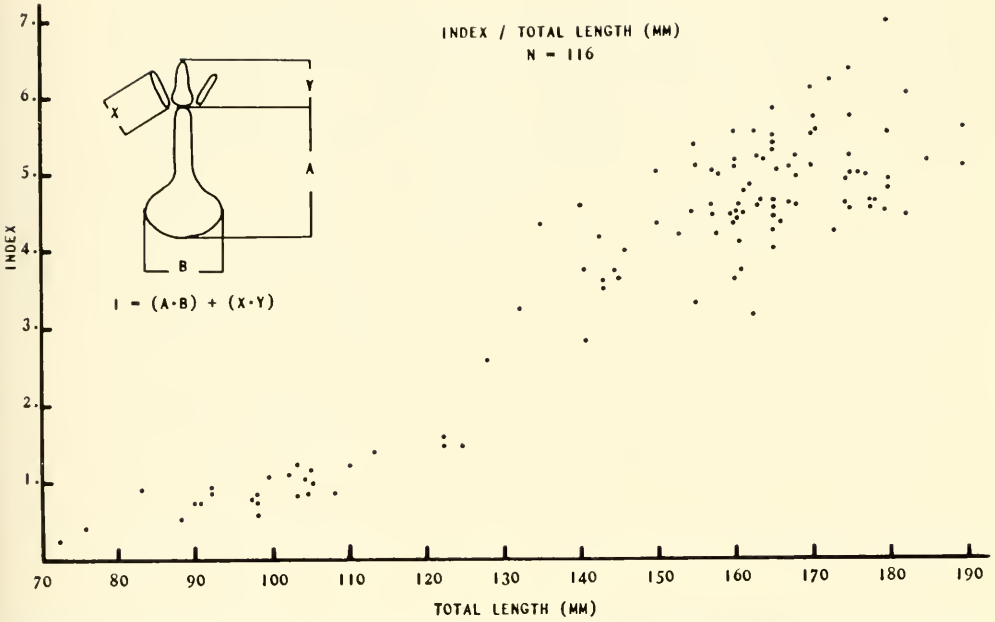


Figure 14. Comparison of the total lengths of 116 *Microtus montanus* to their bacular indices.

dependent more upon total length than upon chronological age of the animal, is summarized in data presented in Table 2. Data on animals of two size classes (160-165 mm and 180-189 mm) were selected from the known age *M. montanus* material and known age and total lengths were compared with the lengths of the bacular shafts and the bacular indices. Although the length of the shaft was essentially the same in both size classes, the bacular index of the larger size group was significantly greater than that of the smaller group of animals ($t=3.85$ at 27 degrees of freedom; significant at .001 level). Further, the average age of the 160-165 mm group was 186 days, whereas that of the 180-189 mm group was only 152 days (Table 2). The small number of animals in the respective classes disallows significant statistical results, however.

In our laboratory stock of *Microtus montanus*, both males and females reach sexual maturity at about 5 weeks of age at which time the average total length is approximately 130 mm. That total length of the baculum shows much greater variation after 35 days of age, suggests that physiological factors may influence bacular development This is further implied by closer relation of the bacular index to body length than to age (Figure 12). Apparently, individual differences in physiology and genetics may account for the greater variability in bacular size once sexual maturity is reached. Perhaps the gonadotropic hormones of the adenohypophysis or the gonadal hormones

TABLE 2.

Comparison of the length of the shaft of the baculum and the bacular index (see text for explanation) in two size classes of adult Microtus montanus.

Size Class (Total length of the individual)	Number of individuals in size class	Number of known-age individuals	Length of the shaft of the baculum	Bacular Index	Age (Days)
160-165 mm	20	13	2.3-2.9 mm ($\bar{x} = 2.5$)	3.1-5.5 ($\bar{x} = 4.6$)	79-243 ($\bar{x} = 186$)
180-189 mm	9	4	2.3-3.0 mm ($\bar{x} = 2.6$)	4.4-7.2 ($\bar{x} = 5.4$)	105-172 ($\bar{x} = 152$)

may exert some influence on bacular development. The general body size attained by an individual is regulated largely by genetic factors, but individual variations in size within a species may well be based more on physiological differences. Thus, an individual possessing a more active (or larger) anterior pituitary (producing more somatotropin) may grow faster and larger than another of its own species. Similarly, a more active pituitary might also release greater amounts of gonadotropins and release of more adrenal androgens may influence the possible relationship of bacular growth to sexual maturity and total length (as a measure of size of the individual) in *Microtus*. Presumably, elucidation of endocrine relationships to bacular development can be readily accomplished for many mammals by experimental procedures in the laboratory using known-age animals.

It is perhaps surprising that endocrine effects on such a taxonomically important element as the baculum have not been noted by mammalogists before, as they are well recorded in the literature. A response in baculum size (associated with general massive development of all parts of the male reproductive tract) in *Rattus* to androgens has been recorded by Korenchevsky et al. (1932) and Thyberg and Lyons (1948).

Howard (1959) referring to gonadectomized mice (*Mus*) states: "not only is there an increase in lengths of the bone (i.e. baculum) with DHA (dehydroepiandrosterone), but the changes in shape and thickness are striking." A similar response is produced by administration of 11-hydroxy-androstenedione (an adrenal androgen) to gonadectomized mice (Howard, op. cit.).

These data suggest that chronological age cannot be ascertained in *Microtus* by measurements of a number of parameters of the baculum. We suspect that the same is true for other rodents with the complex type of baculum. Total bacular size (as indicated by the index herein employed) appears to be possibly a function of hormonal activity and physiological, rather than chronological, age.

Other than differences directly attributable to size, considerable individual variation was noted in the bacula of *M. montanus*. Figure 15 illustrates a series of bacula demonstrating the extremes of variability observed in the 117 males studied. The base of the shaft is usually a crudely shaped diamond without a basal notch. In some (Figure 15E), a notch is present. In others the shape of the base varies from roughly triangular (Figure 15D) to oblong (Figure 15H), often with an irregular, rugose proximal edge (Figure 15G). The spine of the shaft is more constant in form than the base, though occasional medial or terminal swellings are evident (Figures 15B and 15I). The "spurs" or sequelae, mentioned above, are often present near the synovial joint associating shaft and distal processes (Figure 15B and 15J). These latter elements are highly variable. The calcified portion of the median process may be simple rod-like (Figure 15C, 15E, and 15G) or may be expanded near its base (Figure 15A, 15F, 15H, and 15J). Although this expansion is generally associated with greater age or total length of the individual, exceptions were noted.

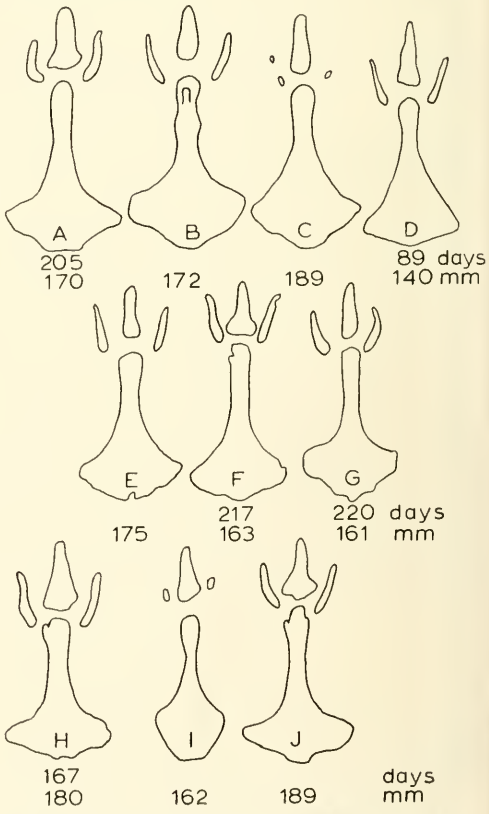


Figure 15. Ten bacula of *Microtus montanus* illustrating individual variation. Ages and total lengths of the individuals from which the bacula were taken are given below the figures.

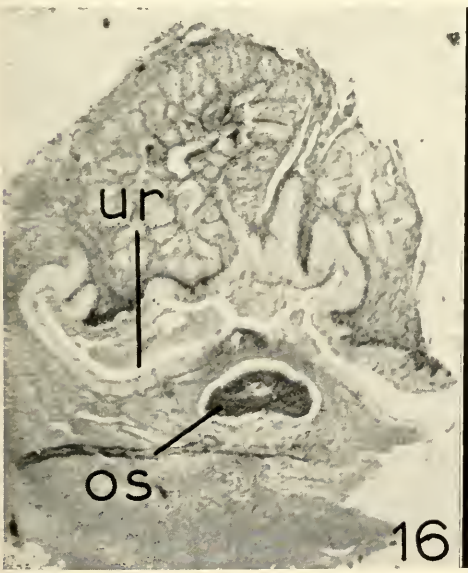
The lateral distal processes vary greatly between individuals and sometimes between members of the same pair. Calcification, even in large, adult animals, may be complete or incomplete, and may, in each process, result from one or occasionally two, centers of calcification (Figure 15C). If fully calcified, these processes may curve inward (Figure 15A and 15G), or remain straight (Figure 15D and 15E). The tips occasionally curve outward. Viewed laterally the lateral processes vary in their relation to the median process and the shaft, sometimes lying in the same plane as the shaft or declinating by as much as a 45° angle (Figure 9).

In the *Microtus* studied, the lateral processes are the last to calcify and occasionally they may not do so. In large microtines (e.g.*Ondatra*) these elements are large and usually well calcified. *Pitymys,* one of the smaller microtines, is often characterized by the poor development of these processes. Possibly the different degrees of calcification seen in a group such as the microtines may be more a function of the average or maximum size obtained by the form than a morphological characteristic, per se.

C. *Os Clitorides in Muroid Genera with Complex Bacula*

As homologs of the penis, clitoral elements are of interest as they often demonstrate what may be interpreted as either rudimentary or reduced conditions of the male structures. In some rodents, especially the sciurids, the os clitoridis is a small, clearly homologous, version of the baculum (Layne, 1954). This is not the case in the muroids examined.

In muroids the clitoris forms a small replica of the penis. The urethra is enclosed within the clitoris in *Mesocricetus, Ondatra* (Figures 16 and 17) and *Microtus.* Distally the clitoris terminates in three lobes of tissue, homologous with the anlagen of the three distal processes of the baculum. Cartilaginous tissue is present in these lobes in the genera examined. In *Ondatra* the fibrocartilage of the median lobe calcifies in large individuals (Figures 17 and 18A), and although we have not observed calcifications in the lateral processes, they possibly may occur in some individuals. The only other microtines in which the os clitoridis has been reported are *Microtus californicus* and *M. longicaudus* (Ziegler, 1961). The illus-



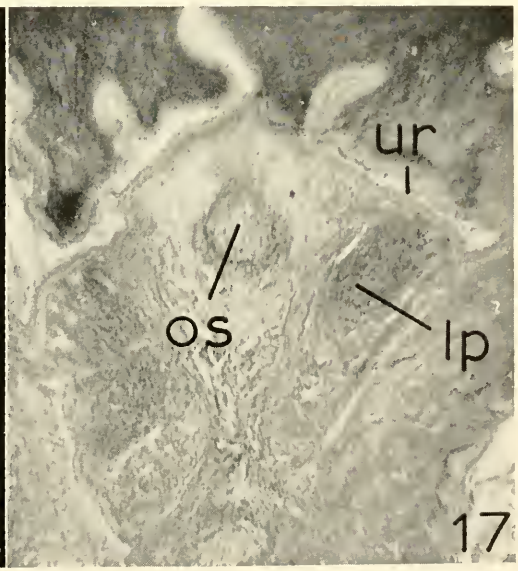


Figure **16**. Cross-section of the clitoris of *Mesocricetus auratus* showing the true bony nature of the os clitoridis (os). Figure **17**. Cross-section of the clitoris of *Ondatra zibethicus*, showing the homologs of the lateral processes of the baculum (lp), and the median process with a calcified fibro-cartilage "os clitoridis" (os). The urethra (ur) is visible in both Figures 16 and 17.

trations of these specimens suggest that they are of the same type as that of *Ondatra.* We have examined 21 female *Microtus montanus* ranging in total length from 145-166 mm, and in age from 212-245 days, but have observed no calcification following Alizarin Red staining. Fibro-cartilage is present in the median lobe, however, and under favorable conditions might calcify. Ziegler (1961) suggests that the occurrence of the os clitoridis in *Microtus* may not be associated with age, as it is found in both young and old animals.

The os clitoridis of *Mesocricetus* is quite different from that of the microtines. In *Mesocricetus* the element is located more proximally and has a more definitive shape (Callery, 1951). Sectioning reveals that this is true bone (Figure 16), histologically identical to the shaft of the baculum. Its proximal location in the clitoris confirms this homology (Figure 18B). No calcifications were noted in the three large, loosely cartilaginous lobes of tissue present distally in *Mesocricetus.*

The "os clitoridis" of *Mesocricetus* is not homologous to those of *Ondatra* and *Microtus,* as each is homologous to a different part of the complex baculum. The "os clitoridis" of *Mesocricetus* is the only one observed that can properly be termed a bony element.

D. *Taxonomic Implications*

The continuing use of the baculum and other phallic structures in mammalian, especially muroid, systematics, suggests the desirability of much more information on the development, individual variability, microstructure, and physiological and chronological relationships of these elements before sound taxonomic interpretations can be based on them.

From the data presented above, bacular structures obviously are subject, at least at the population and infraspecific levels, to considerable variability. Such observable differences may be dependent upon a plethora of variables, including the endocrine state of the individual, chronological age, genetic background, etc.

The degree of such variability, and the importance of the endocrine state, as well as the nature of the calcifications observed in the distal processes in this study, cast doubt on the utility of minor differences in

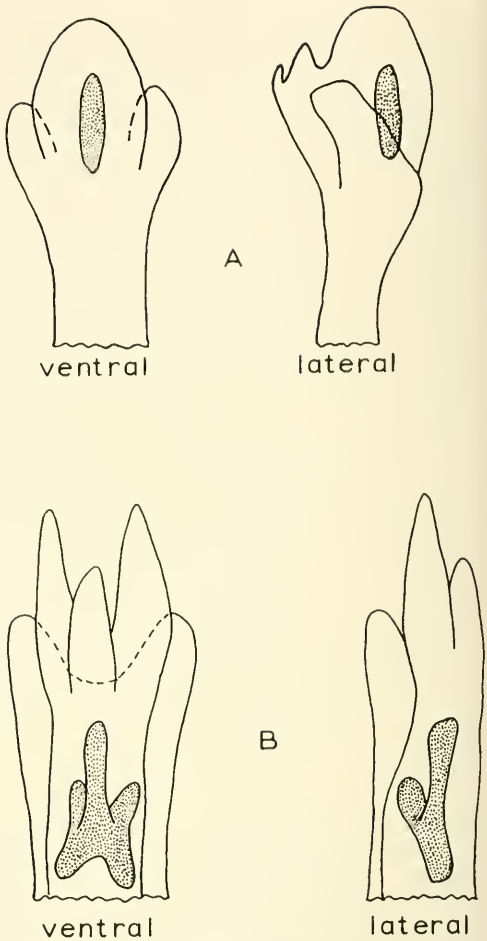


Figure 18. Clitorides of two cricetids, *Ondatra zibethicus* (A) and *Mesocricetus auratus* (B), illustrated in ventral (urethral) and lateral views. The "os clitoridis" of each is stippled.

form and size of the complex baculum in systematic studies at the lower taxonomic levels in those rodents in which it occurs.

The source of specimens employed in such studies also seems to be of considerable importance. Unfortunately, many specimens available in collections, and often used in morphological and systematic studies, have been aged on such criteria as the condition of the pelage and/or the size of the testes and epididymides. Whereas such criteria may determine "ecologically adult" individuals (i.e. individuals functioning as sexually mature entities in a population), they provide no reliable information on the true chronological or physiological age of the

individual. Since only a small percentage of rodents seem to achieve full morphological adulthood under natural conditions, laboratory colonies of known age animals can perhaps provide better material for comparative morphological studies of male reproductive organs and systematic studies based on these elements than can be obtained in the field.

This does not mean to imply that observable differences do not exist between the bacula of different muroid rodents, particularly at, and above, the generic level. At these levels gross differences in proportions and/or dimensions can generally be substantiated as has been shown by Hooper (1960 and other papers) and Hooper and Musser (1964). Even at these levels, however, it would seem imperative to understand something of the development of the baculum, or at least to select bacula from individuals of large size as these may represent the maximum, and therefore characteristic development of the form involved, reducing the variability caused by the endocrine state, diet, and other factors.

Above the generic level basic anatomical patterns of bacular development and form, as well as association with other structures of the glans penes should be similar within phylogenetically related groups. Within the Rodentia such information is currently only available within the myomorphs, and the similarity of the baculum or the complete glans penis in diversely classified muroids has been noted for some time. Hamilton (1946) compared *Oryzomys* and *Sigmodon* to the microtines. Hooper and Musser (1964) in a study of the glans penes, considered cricetids and murids to represent a single family (Muridae). Arata (1964), studying the male accessory reproductive glands, demonstrated that a basic pattern existed in murids and cricetids, and suggested that only one family was represented. Hershkovitz (1962) discounted the commonly accepted differences in dental pattern between the murids and cricetids and recognized only a single family (Muridae), preferring the evidence afforded by the phallus.

The similarity of bacular form in *Rattus* and the cricetids examined in this study supports the thesis that murids and cricetids represent but a single family. The development of the baculum of *Rattus* described by Ruth (1934), and the presence of a movable joint between proximal and distal elements of the baculum of *Rattus* and the cricetids noted in this report suggests that basic homologous morphological forms are represented.

Although all cricetids examined by us have calcified fibro-cartilage distal elements as contrasted to the bony distal processes of *Rattus*, far too many muroids remain unexamined, and little systematic significance can be placed on this difference at this time.

The fusion of the distal elements seen in *Rattus* is greater than that observed in the cricetids, but is probably derived from the basic cricetid pattern. Hooper and Hart (1962) note similar trends in microtines, and Hooper and Musser (1964) point out that this trend may have occurred several times, and is evident in microtines, murines, South American cricetines and Old World cricetines, producing secondarily simple penes, derived from an ancestral complex stock. Bittera (1918) previously suggested that such reductions were secondary. The evidence produced by a study of the male accessory reproductive glands (Arata, 1964) also suggests that certain glandular complements, usually present along with the complex baculum occurs in muroids (including cricetines, microtines, and murines), and is variously reduced in different subgroups.

Thus, the data presented above reinforce the importance of the baculum and associated phallic structures in studies of muroid rodents at the generic level and above, and suggest caution concerning the utilization of the baculum alone at specific and subspecific levels in rodents in which the complex type is present.

IV. Acknowledgments

The authors thank Mr. J. Howard Hutchison for drawing Figure 1 and Mr. Larry H. Ogren for aid in collecting specimens of *Ondatra* and *Myocastor* used in this study.

The senior author carried out part of this work under the auspecies of the American Cancer Society (Grant No. IN 24-E) and the National Science Foundation (G B 2458). Mrs. Downs (Martha C. Sapp) participated in this study while a recipient of a National Science Foundation Undergraduate Research Fellowship at Tulane University (Newcomb College). Availability of the *Microtus montanus* utilized in this study was made possible

by support from the National Science Foundation (188926), U. S. Atomic Energy Commission (AT-40-1-1831) and the New Orleans Cancer Association.

V. References Cited

Anderson, Sydney 1960. The baculum in microtine rodents. Univ. Kans. Publ. Mus. Nat. Hist. 12: 181-216.

Arata, Andrew A. 1964. The male accessory reproductive glands of muroid rodents. *Bull. Florida State Mus., Biol. Sci.* 9: 1-42.

Bittera, Julius 1918. *Einiges über die männlichen Kopulations-organe der Muriden und deren systematische Bedeutung. Zool. Jahrb., Abl. Systematik.* 41: 399-418.

Callery, R. 1951. Development of the os genitalia in the golden hamster, *Mesocricetus (Cricetus) auratus. J. Mammal.* 32: 204-207.

Dearden, L. C. 1958. The baculum in *Lagurus* and related microtines. *J. Mammal.* 39: 541-553.

Elder, W. H. and C. E. Shanks 1962. Age changes in tooth wear and morphology of the baculum of muskrats. *J. Mammal.* 43: 144-150.

Gilbert, T. H. 1892. *Das os priapi der Saugethiere. Morph. Jahrb.* 18: 805-831.

Hamilton, W. J., Jr. 1946. A study of the baculum in some North American Microtinae. *J. Mammal.* 27: 378-386.

Hershkovitz, Philip 1962. Evolution of neotropical cricetine rodents (Muridae) with special reference to the phyllotine group. *Fieldiana: Zoology.* 46: 1-524.

Hooper, Emmet T. 1960. The glans penis in *Neotoma* (Rodentia) and allied genera. *Occ. Pap. Mus. Zool., Univ. Mich.* No. 618: 1-20.

Hooper, Emmett T. and B. S. Hart 1962. A synopsis of North American microtine rodents. *Misc. Publ., Mus. Zool., U. Mich.* No. 120: 1-67.

Hooper, Emmet T. and Guy G. Musser 1964. The glans penis in Neotropical cricetines (Family Muridae) with comments on classification of muroid rodents. *Misc. Publ., Mus. Zool., U. Mich.* No. 123: 1-57.

Howard, Evelyn 1959. A complementary action of corticosterone and dehydroepiandrosterone on the mouse adrenal, with observations on the reactivity of reproductive tract structures to dehydroepiandrosterone and 11-hydroxy-androstenedione. *Endocronol.* 65: 785-801.

Korenchevsky, V., M. Dennison and A. Kohn-Speyer 1932. The rat unit of testicular hormone. *J. Biochem.* 26: 2097-2107.

Layne, James N. 1954. The os clitoridis of some North American Sciuridae. *J. Mammal.* 35: 357-366.

Ruth, E. B. 1934. The os priapi: a study in bone development. *Anat. Rec.* 60: 231-249.

Simpson, George G. 1945. Principles of classification and a classification of mammals. *Bull. Amer. Mus. Nat. Hist.* 88: 1-350.

Taylor, J. Mary 1961. Reproductive biology of the Australian bush rat, *Rattus assimilis. U. Calif. Pub. Zool.* 60(1): 1-66.

Thyburg, W. G., and W. R. Lyons 1948. Androgen-induced growth of the os penis of hypophysectomized-gonadectomized rats. *Proc. Soc. Exp. Biol. and Med.* 69: 158-161.

Tullberg, Tycho 1899. *Ueber das System der Nagethiere, eine Phylogenetsche Studie. Nov. Acta. Reg. Soc. Upsala,* ser. 3, vol. 18: 329-541.

Ziegler, Alan C. 1961. Occurrence of os clitoridis in *Microtus. J. Mammal.* 42: 101-103.

ETHEOSTOMA **DITREMA**, A NEW DARTER OF THE SUBGENUS *OLIGOCEPHALUS* (PERCIDAE) FROM SPRINGS OF THE ALABAMA RIVER BASIN IN ALABAMA AND GEORGIA

JOHN S. RAMSEY
and
ROYAL D. SUTTKUS,
Department of Zoology,
Tulane University,
New Orleans, Louisiana 70118

ABSTRACT

Etheostoma (Oligocephalus) **ditrema** is described from 133 specimens from three localities in the upper Coosa-Alabama River basin. It is restricted in habitat to springs and spring-fed ponds above the fall line. It is a small, sexually dimorphic species most closely related to but sharply differentiated from *E. swaini* of the eastern Gulf Coastal Plain. Infraspecific variation is marked. *E.* **ditrema** is unusual among percids in typically possessing two coronal pores, which, when considered with other characters, suggests that it is a paedomorphic species of the *E. asprigene* species group.

The subgenus *Oligocephalus* is the most complex and speciose group of those comprising the North American darter genus *Etheostoma.* The members of the group were delimited by Bailey and Gosline (1955), who recognized 19 nominal species. Strawn and Hubbs (1956) recognized *Etheostoma lepidum* (Baird and Girard) as a species distinct from *E. grahami* (Girard). Yerger (1960) resurrected *E. okaloosae* (Fowler) from the synonymy of *E. swaini* (Jordan), and included it in the subgenus *Villora. Etheostoma spilotum* Gilbert was reduced to a subspecies of *E. sagitta* (Jordan and Swain) by Kuehne and Bailey (1961). Distler and Metcalf (1962) described *E. pallididorsum,* which may prove to be a subspecies of *E. cragini* Gilbert. With the definition of the subgenus *Oligocephalus* and the redescription of *E. hopkinsi* (Fowler) by Bailey and Richards (1963), the number of recognized nominal species in the group was brought to 21.

Etheostoma **ditrema** was first collected by Jordan (1876) in millponds of the region of Rome, Floyd Co., Georgia. However, he misidentified his specimens as *Boleichthys elegans* Girard, which is probably a synonym of *E. grahami,* a species of southwestern United States and northeastern Mexico.

We discovered the new darter during the spring of 1962, in a spring tributary to the Coosa-Alabama river system in northwestern Georgia. Later another spring locality in northeastern Alabama was brought to our attention.

We acknowledge gratefully the assistance of the following. Clyde D. Barbour, William T. Mason, Jamie E. Thomerson, and members of the Tulane University Summer Program in Environmental Biology for 1964 aided in the collection of material. Richard D. Caldwell and W. Mike Howell (University of Alabama) apprised us of the existence of the Alabama population of **ditrema** and have given information on their collecting efforts in springs of northeastern Alabama. Dr. Herbert T. Boschung loaned material from the University of Alabama Ichthyology Collection (UAIC). Dr. Bruce B. Collette discovered and notified us of a single specimen of **ditrema** remaining from Jordan's

EDITORIAL COMMITTEE FOR THIS PAPER:

BRUCE B. COLLETTE, Acting Director, Ichthyological Laboratory, U. S. National Museum, Washington, D. C.

LESLIE W. KNAPP, Supervisor for Fishes, Oceanographic Sorting Center, U. S. National Museum, Washington, D. C.

GEORGE A. MOORE, Professor of Zoology, Oklahoma State University, Stillwater, Oklahoma

collection in the region of Rome, Georgia. He allowed us to examine this specimen while he had it on loan from the Academy of Natural Sciences of Philadelphia (ANSP). Miss Winona H. Welch (De Pauw University) identified aquatic mosses from the type locality. Assistance in field work was made through National Institutes of Health grants WP-00082-04, 05 and 3-T1-ES-27-01S1, 02S1, and National Science Foundation NSF G-23598 to Suttkus, and NSF G-17005 to Ramsey through the Highlands Biological Station, Inc., North Carolina.

Etheostoma (Oligocephalus) **ditrema** new species

Coldwater darter

(Figs. 1-3)

Boleichthys elegans.—Jordan, 1876: 308-309 (misidentification).

Material.—Description is based on 133 specimens from three localities in the Coosa-Alabama river drainage. The holotype, TU 35703, an adult male 33.9 mm in standard length, was collected in a spring flowing into a small tributary to Mills Creek, tributary to Chattooga River, 4.3 airline miles due west of Lyerly, Chattooga Co., Georgia (0.2 miles ENE of the Alabama boundary), on the Broomtown (Ala.)-Foster's Store-Lyerly road (T7S, R11E, Section 28) on 18 July 1962. Taken with the holotype were 21 paratopotypes (TU 29153, 15-35 mm s.l.). Other paratopotypes were taken 19 April 1962 (TU 26086, 8: 24-31), 30 May 1962 (TU 27566, 9: 18-34), 1 June 1964 (TU 32762, 34: 19-42), and 23 June 1964 (TU 32981, 43: 20-39). Five paratopotypes from TU 32981 have been distributed to each of the following institutions: USNM 198607, United States National Museum; MCZ 43123, Museum of Comparative Zoology, Harvard University; ANSP 101231, Academy of Natural Sciences of Philadelphia; UMMZ 187501, University of Michigan, Museum of Zoology; CU 47872, Cornell University; SU 62401, Stanford University.

A paratype (ANSP 20649, 1: 23) was collected during the summer of 1876 from a millpond (Etowah River drainage) near Rome, Floyd, Co., Georgia.

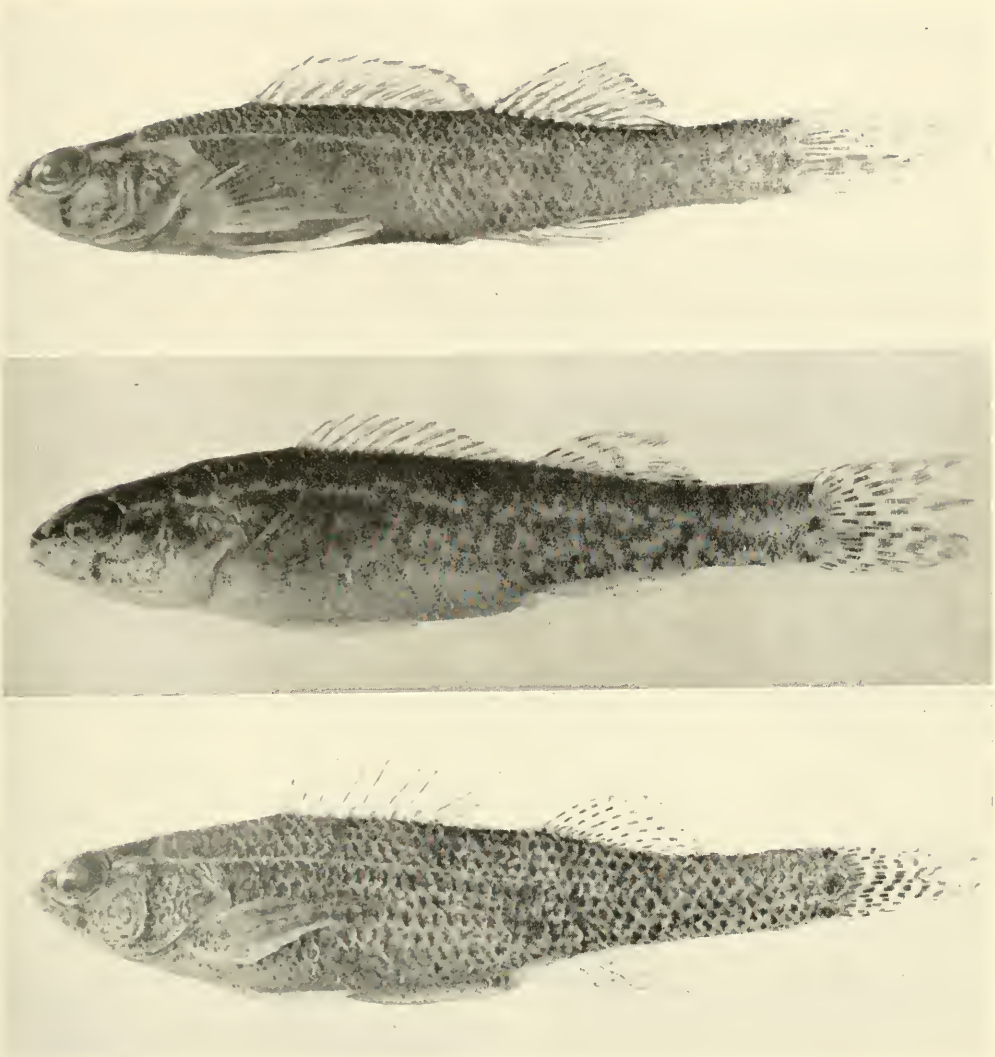
Specimens from a third population, not designated as type material, were captured in Coldwater Creek, tributary to Choccolocco Creek, immediately below Coldwater Spring (T16S, R7E, Section 29), at Coldwater, 5.7 miles W of Oxford, Calhoun Co., Alabama, about 500 yards north of U. S. Highway 78, on 28 January 1964 (UAIC 1138, 1: 38), 1 June 1964 (TU 32746, 9: 26-41), and 31 August 1964 (TU 34400, 6: 20-32).

Several series of *Etheostoma swaini* from the Alabama River drainage were used for comparison with **ditrema.** These include TU 9497 (2: 43-55), Ala., Montgomery Co., creek 12.6 miles east of Montgomery, Highway 80; TU 34016 (5: 20-38), Ala., Clarke Co., Sand Hill Creek 1.1 miles west of Choctaw Bluff; TU 35176 (37: 22-48), Ala., Dallas Co., Pine Flat Creek 6 miles south of Selma. The problem of geographic variation in *swaini* and in the *asprigene* complex is being reported elsewhere.

Counts and measurements were made following Hubbs and Lagler (1958), except transpelvic width, the distance between the outer bases of the pelvic spines when held parallel (Bailey and Richards, 1963). The cephalic lateralis canals were analyzed following Hubbs and Cannon (1935).

Diagnosis.—A small, moderately robust species of the subgenus *Oligocephalus.* Lateral line moderately arched and incomplete, pored lateral-line series terminating between the level of the posterior base of the spinous dorsal fin and posterior soft dorsal base; total lateral-line scales 41 to 54, pored scales 19 to 35, unpored scales 13 to 30. Coronal canal incomplete, usually two coronal pores; infraorbital canal complete; supratemporal canal usually interrupted. Branchiostegal membranes overlapping anteriorly. Nape naked to completely scaled; breast usually scaled, rarely naked; prepectoral region, cheeks, opercles, and posterolateral corners of top of head scaled. Dorsal fin-rays VIII to XII—9 to 12; anal II, 6 to 8; pectoral 11 to 13. Nuptial tubercles absent. Vertebrae 35 to 37. Breeding male dark brown with orange pigment on belly and lower caudal peduncle; female indistinctly mottled with dark brown. Submarginal orange band present in spinous dorsal fin of both sexes. Humeral dark spot absent. Three dark blotches (rarely somewhat ocellate) in a vertical series at caudal fin base.

Description.—*Etheostoma* **ditrema** is a dwarfed species of the subgenus *Oligocephalus.* The largest specimen available is a



Figures 1-3. *Etheostoma* **ditrema**, new species. **1.** (Upper) TU 32762, male paratopotype, 39.0 mm standard length. **2.** (Middle) TU 32762, female paratopotype, 31.9 mm. **3.** (Lower) TU 32746, female, Coldwater Creek, 40.7 mm. Photographs by C. D. Barbour.

male 42.1 mm in standard length, the largest female, 40.7 mm. Adulthood is apparently reached when a standard length of 25 mm is attained. The body is moderately robust but somewhat compressed. The body is widest just behind the head, and deepest at the level of the pelvic fin insertion, except in gravid females. There is a moderate nuchal hump in about half of adult males and in a third of adult females. The caudal peduncle is moderately slender. These and other proportional measurements are listed in Table 1.

The head is of moderate length, about 30 percent of standard length. The snout is gently to abruptly decurved and short, its length usually less than orbit length. The upper and lower profiles of the snout meet at an angle of 55° to 85°. The projected angle formed by the upper and lower head surfaces behind the eye ranges from 19° to 30°. The frenum is always well-developed,

TABLE 1.
Measurements of Etheostoma **ditrema** *in thousandths of standard length*

Catalog Number	TU 35703 Holotype	TU 26086 27566, 29153 Paratypes		TU 26086 29153 Paratypes	
Number of specimens	1	9		10	
Sex	♂	♂		♀	
		Range	$\bar{x}$[1]	Range	$\bar{x}$
Standard length (mm)	33.9	24.9-33.7	(30.4)	26.7-35.3	(31.3)
Predorsal length	348	346-367	(353)	358-371	(358)
Anal origin to snout	644	619-656	(641)	634-668	(650)
Body depth	209	190-208	(199)	190-228	(206)
Distance from soft dorsal origin to anal origin	180	157-175	(169)	149-176	(161)
Body width	142	121-138	(130)	124-153	(139)
Caudal peduncle length	233	227-265	(244)	227-272	(245)
Caudal peduncle depth	106	97-109	(103)	90-111	(100)
Head length	307	294-312	(320)	280-317	(300)
Head depth	174	165-177	(171)	159-180	(166)
Head width	136	125-145	(137)	129-149	(137)
Lower jaw symphysis to juncture of gill membranes	127	115-149	(132)	126-152	(136)
Pelvic insertion to juncture of gill membranes	192	167-192	(180)	180-198	(185)
Orbit length	74	76-89	(80)	72-90	(80)
Snout length	71	54-72	(66)	59-75	(65)
Upper jaw length	86	80-96	(87)	82-95	(87)
Width of gape	74	72-85	(79)	70-83	(76)
Interorbital width, least fleshy	50	48-64	(55)	37-54	(50)
Spinous dorsal base	274	260-289	(276)	252-288	(269)
Longest dorsal spine	97	85-112	(99)	67-99	(85)
Soft dorsal base	177	158-197	(176)	142-184	(166)
Longest dorsal soft ray	174	131-159	(143)	127-153	(139)
Soft dorsal, depressed length	254	218-273	(252)	221-257	(236)
Longest anal soft ray	142	119-154	(140)	113-138	(128)
Anal fin base	124	94-136	(121)	96-115	(107)
First anal spine	86	69-95	(84)	65-87	(74)
Anal, depressed length	200	205-230	(216)	192-214	(199)
Longest pectoral ray	200	187-245	(207)	158-216	(191)
Pelvic fin length	209	186-223	(265)	173-194	(185)
Pelvic fin base	32	32-39	(35)	33-39	(36)
Interpelvic distance	15	10-16	(13)	10-19	(14)
Transpelvic width	71	61-67	(65)	62-72	(66)
Caudal length	206	190-232	(209)	187-216	(203)

[1] Holotype included in mean for males.

although frequently narrow. The mouth is terminal or slightly subterminal, and projects posteriorly and downward to or slightly beyond the anterior edge of the eye. The prevomer and palatine bones bear teeth. The upper surface of the eye in lateral aspect is even with the top of the head. The gill membranes are usually separate and overlapping anteriorly, occasionally very slightly conjoined. There are six branchiostegal rays on each side.

The lateral line is incomplete, and is elevated and arched anteriorly, beginning the downward arc at about the level of the spinous dorsal origin. The pored lateral line terminates at the level of a point between the posterior spinous dorsal and posterior soft dorsal bases.

The infraorbital canal is usually complete (interrupted on one side in one of 22 type specimens and in two of 16 specimens from the Choccolocco Creek drainage; interrupted on both sides in one specimen from the Choccolocco locality, pores 2+5 - 5+2). Infraorbital pores usually number 8 (5 to 9). The preoperculomandibular canal is typically complete, usually with 10 pores (rarely 8 or 11, frequently 9). The supratemporal

canal is usually interrupted, each branch having 2 pores (Table 5). The lateral canal normally has 5 pores.

An unusual diagnostic feature is the possession of two well defined coronal pores in most specimens (Table 5), which results from the non-fusion of the two coronal canals branching mesially from the supraorbital canals. In all other species of *Oligocephalus,* and in other percid subgenera, these branches fuse to form a backward-projecting tube terminating at the coronal pore. In *E.* **ditrema** the two coronal branches emerge side-by-side just posterior to a line between the upper orbital rims. The two pores may fuse as one, but there is rarely a tube directed caudad to the pore. There are in addition four pores in the supraorbital canal, although infrequently one interorbital pore is absent. Rarely, one of the coronal branches has failed to develop.

Scale row counts (Tables 2 and 3): total lateral-line scales number 41 to 54 (usually 44 to 50), pored lateral-line scales 19 to 35 (usually 22 to 32); unpored lateral-line scales 13 to 30 (usually 16 to 26); transverse body scales (from soft dorsal origin posteroventrally to anal fin base) 11 to 14 (usually 12 or 13); scales above lateral line 3 to 5 (usually 4); scales below lateral line 6 to 9 (usually 7 or 8); caudal peduncle scales 17 to 22 (usually 19 to 21).

Squamation: The opercles, cheeks, belly, and prepectoral region are wholly invested with exposed ctenoid scales. There are a few scales embedded on the head just above and anterior to the junction of the supratemporal and lateral canals. The breast is naked anteriorly. The posterior breast is usually scaled, although some infraspecific variation exists. The type material from the Chattooga and Etowah drainages in Georgia usually has exposed ctenoid breast scales. Occasionally the scales are embedded, or a narrow median strip is naked, but the breast is never entirely scaleless. Of the 16 specimens available from Coldwater Spring, only one has exposed ctenoid breast scales, 10

TABLE 2.
Distribution of scale row counts in Etheostoma **ditrema** *and E. swaini. Value for holotype of* **ditrema** *in boldface*

Species and drainage	Total lateral-line scales																
	39	40	41	42	43	44	45	46	47	**48**	49	50	51	52	53	54	N
ditrema																	
Chattooga			1	1	3	6	16	22	18	11	16	10	4	—	—	1	109
Etowah									1[r]	—	1[l]						1
Choccolocco					1	3	4	—	2	2	2	—	1				15
swaini																	
Alabama	1	4	3	2	8	7	10	1	5	2	—	1					44

	Caudal peduncle scales							Soft dorsal origin to anal base				
	17	18	19	**20**	21	22	N	11	**12**	13	14	N
ditrema												
Chattooga		3	41	33	28	3	108	2	65	40	2	109
Etowah		1					1		1			1
Choccolocco	1	1	8	3	1		14		14	1		15
swaini												
Alabama	1	4	11	15	10	3	44	5	23	14	2	44

	Scales above lateral line						Scales below lateral line					
	3	**4**	5	6	7	N	6	**7**	8	9	10	N
ditrema												
Chattooga	3	53	20			76	2	30	31	7		70
Etowah		1				1		1				1
Choccolocco		14	1			15	1	10	4			15
swaini												
Alabama		3	35	5	1	44	5	20	15	3	1	44

[r, l] Both sides of single specimen used: r = right, l = left

TABLE 3 (continued on opposite page)
Lateral line scales in Etheostoma **ditrema** *and E. swaini. Value for holotype in boldface.*

Species and drainage	Pored lateral-line scales											
	19	20	21	22	23	24	25	26	27	**28**	29
ditrema											
Chattooga	3	2	2	3	7	8	11	15	12	12	11
Etowah								1[l]	1[r]		
Choccolocco		1	1	1	2	1	—	2	3	3	—
swaini											
Alabama											

	Unpored lateral-line scales												
	4	5	6	7	8	9	10	11	12	13	14	15	16
ditrema													
Chattooga										1	2	3	7
Etowah													
Choccolocco													
swaini													
Alabama	1	3	9	10	10	3	2	5	1				

have scattered, embedded ctenoid scales, and 5 have the breast completely naked.

Nape squamation is variable (Table 6). Specimens from Coldwater Spring tend to have the nape more fully scaled than in type specimens. The notation used for the degree of nape squamation in Table 6 was derived from a relative scale. A value of zero signifies that at least the median portion of the nape from the spinous dorsal origin to the occiput is naked; I through III represent successive increases in posterior nape squamation; IV, nape wholly scaled but scales embedded at least anteriorly; V, nape completely invested with exposed scales.

Fins (measurements in Table 1): The spinous dorsal is composed of 8 to 12 slender spines. Many specimens have small postapical fleshy enlargements at the spine tips similar to those in other species of *Oligocephalus*. The fin is low; the length of the longest spine (located at the fin center) is about two-fifths to one-half the length of the fin base, and can be stepped into head length two and one-half to three times. The fin border in both sexes usually forms a gentle arc rearward to the dorsum (not subquadrate in outline, as in *E. swaini*). The soft dorsal fin is usually well separated from the spinous dorsal (as in Fig. 2). There is typically a much broader hiatus between the fins in the Choccolocco population (Fig. 3). Though low, the soft dorsal is higher than the spinous dorsal. Dorsal soft rays number 9 to 12. Total dorsal rays range from 18 to 23. The Choccolocco population has fewer dorsal rays (Table 4), which probably is correlated with the greater dorsal fin separation.

The anal fin is also small. There are usually two spines (one specimen out of 133 has a single spine, and two have three spines). The second spine is usually more slender than the first. The second spine in the Choccolocco population is usually stiff, but is typically very slender and flexible in specimens from Georgia. Anal soft rays number 6 to 8 (usually 7).

There are 11 to 14 (usually 12 or 13) branched caudal rays. The posterior edge of the caudal fin is usually truncate, frequently slightly emarginate or convex. The pectoral fins are short and rounded, the longest ray about two-thirds of head length. Left pectoral rays number 11 to 13 (usually 12). The pelvic fins (rays I, 5) usually extend beyond the posterior edge of the pectoral fin, and are inserted very close together. Interpelvic distance is less than half the width of the pelvic fin base.

Analysis of radiographs of 35 specimens from the type locality revealed the following vertebral counts: 35 vertebrae (one specimen), 36 (17), and 37 (17).

Coloration of males.—The most conspicuous feature of nuptial males is the somewhat muted red-orange pigmentation of the lower body. In several male paratopotypes captured on 1 June 1964, this pigment was distributed almost uninterruptedly from just

TABLE 3 (continued)

Pored lateral-line scales														
30	31	32	33	34	35	36	37	38	39	40	41	42	43	N
7	5	8	2	—	1									109
—	1													1
														15
	2	2	7	4	3	2	7	5	6	3	2	—	1	44

Unpored lateral-line scales														
17	18	19	**20**	21	22	23	24	25	26	27	28	29	30	N
5	19	5	18	19	11	3	6	1	5	3	—	—	1	109
			1[r]	—	—	1[l]								1
4	—	—	1	3	4	—	2	—	1					15
														44

behind the pectoral base to immediately posterior to the anal fin origin, and on the lower caudal peduncle in the form of about five indefinite bar-like groupings of orange scales separated by dull olive-green bars. The orange pigmentation on the caudal peduncle extended dorsad only to the level of the lateral line. Other males had orange pigment before the vent only. Two to four upper body scales in some males also bore orange pigment, but these were scattered and inconspicuous.

In life, and in alcohol, the dorsum is usually uniformly dark brown, broken in most by a predorsal buff-colored nuchal patch of varying width. In some there are about nine very ill-defined darker saddles crossing the dorsal midline and extending laterad on about two scale rows to either side. The intermediate areas between the saddles are brown, similar to the background color, but occasionally are a light brown or buff color. The body at the base of each dorsal fin is buff. In some, the centers of the exposed fields of scales of the dorsum have a slightly darker brown color, giving the impression of vague longitudinal lines extending from the sides of the occiput to the posterior soft dorsal base. The striped pattern extends downward (excluding the lateral line) to the anal base. The stripes are irregularly if at all developed on the lower body, generally being limited to an area on the lateral belly anterior to the anal fin origin and for a short distance on the lower body above the anal fin. There is no humeral dark blotch. The lateral line is less pigmented along the pored portion than on adjoining areas, and appeared yellowish in life, somewhat as in *E. parvipinne* Gilbert and Swain. The unpored lateral-line series appears as an irregular light line. Very faint lateral bars (dull olive-green in life) showing some connection with the dorsal dark saddles are present in many individuals.

There are three black spots (sometimes connected) in a vertical series at the caudal base. Occasionally the lower and/or median spots are faint or absent. The central spot lies at the termination of the lateral-line series just at or immediately behind the posterior edge of the hypural plate. The upper and lower spots lie at the bases of the posterior procurrent caudal rays. The caudal base between the spots is usually lighter than on adjoining areas of the peduncle, and in life there was a small spot of red-orange immediately posterior and mesial to the upper and lower basicaudal dark spots.

The genital papilla and anal rugae are immaculate white. The genital papilla in males takes the form of a short subquadrate flap extending posteriorly to the base of the first anal spine. Occasionally a median short fingerlike projection extends beyond the shorter lateral portions of the papilla.

The lower belly is evenly stippled with micromelanophores. The breast has larger melanophores distributed to the gular region. There is a prepectoral dark blotch.

The head dorsum to the snout is dark brown. The upper snout was buff-colored in life. A dark diffuse line extends from the anterior edge of the orbit below the nostrils to the snout tip, expanding on the anterior third of the upper lip to either side of the buff-colored frenum. The remainder of the upper lip has one or two dark blotches. The posterior maxillary is darkened. The lower lip and lower jaw rami are mottled, and the mandibular symphyseal region usually has a dark blotch. The gular region and branchiostegal membranes are diffusely stippled. There is a postorbital dark streak. The suborbital bar is well-developed, beginning behind the lower orbital midpoint and curving downward and slightly forward on the cheek. The iris was golden-orange in life.

The spinous dorsal fin in life was bordered by a narrow dusky blue band. Proximal to this was a band of red-orange, about three times as wide as the marginal band anteriorly, tapering to an equal width posteriorly. Below this was a slightly wider dusky blue band extending almost to the base of the fin. There was a basal spot of dark red behind each dorsal spine. Nuptial males have melanophores irregularly distributed on the spines.

The soft dorsal fin was dusky blue throughout, always having a basal spot of dark red behind each ray. There was usually some red-orange arranged in one or two indefinite narrow bands mesially and submarginally. There are three or four dark blotches on the rays.

The anal fin was dusky blue-green on both the spined and soft-rayed portion, with basal red-orange spots on the membranes between the soft rays. Some nuptial males had a median band of orange on the rays. Others had several quadrate dark blotches on yellowish rays. The edge of the fin was colorless.

The caudal fin has five to seven irregular dark bars (pigment on rays only). Between the dark bars the rays are yellowish. In a few individuals, the basal portion of the central rays had red-orange pigment extending two-thirds of the distance toward the fin edge. The anterior procurrent caudal rays are embedded in opaque whitish tissue.

TABLE 4.
Distribution of fin-ray counts in Etheostoma **ditrema** *and E. swaini. Value for holotype in boldface.*

Species and drainage	Dorsal spines						Dorsal soft rays						
	8	9	**10**	11	12	N	9	**10**	11	12	13	14	N
ditrema													
Chattooga		2	51	52	7	112		30	71	11			112
Etowah				1		1			1				1
Choccolocco	6	9	1			16	1	8	7				16
swaini													
Alabama		1	21	22		44			19	23	1	1	44

	Total dorsal rays								
	18	19	**20**	21	22	23	24	25	N
ditrema									
Chattooga		1	12	48	44	7			112
Etowah					1				1
Choccolocco	6	3	7						16
swaini									
Alabama			1	9	21	11	1	1	44

	Anal soft rays				Left pectoral rays				
	6	**7**	8	N	11	**12**	13	14	N
ditrema									
Chattooga	40	66	6	112	3	36	29		65
Etowah	1			1		1			1
Choccolocco	5	11		16		10	5		15
swaini									
Alabama	6	31	7	44		5	25	14	44

TABLE 5.
Supratemporal canal and coronal pores in Etheostoma **ditrema** *and E. swaini. Value for holotype in boldface.*

Species and drainage	Supratemporal canal			Coronal pores		
	Complete	**Interrupted**	N	1	**2**	N
ditrema						
Chattooga	30	86	116	45	68	113
Etowah		1	1	1		1
Choccolocco	5	11	16	8	8	16
swaini						
Alabama	20	24	44	44		44

The pectoral fins are colorless save for a scattering of dusky along the entire length of the rays.

The tissue investing the pelvic spine is only very slightly thickened, and is colorless save for a sprinkling of micromelanophores. The soft-rayed portion had dusky blue-green (darkest between the posterior rays) along the basal two-thirds of the rays and interradial membrane. The distal third of the membrane is colorless. The distal portions of the rays have scattered melanophores.

Only two young males are available from the Choccolocco locality. These had submarginal and basal red-orange bands in the spinous dorsal fin, but lacked the orange pigment on the venter.

Coloration of females.—Females were devoid of erythric pigment on the body. In alcohol the general body coloration is similar to that of males, save they tend to be more mottled, especially on the venter. Choccolocco females are darker and less mottled, and occasionally the basicaudal dark spots are somewhat ocellate (Fig. 2 and 3).

Only one female from the Chattooga population had a submarginal pale orange band in the spinous dorsal, but all adult females from the Choccolocco locality possessed this coloration. Females usually have a dusky marginal band, which tends to be obsolete anteriorly. There are brownish streaks in the median interradial membranes along the spines. Dusky spots occur basally in the interradial membranes. The spines are variously marked with one or two elongate dusky blotches.

The soft dorsal fin is marked with four or five indefinite bands of brownish pigment, which is distributed on the interradial membranes distally and on the rays basally. There is a basal series of interradial dark blotches. The soft dorsal bands are more discrete and narrower in Choccolocco females.

The caudal fin is barred with five to seven irregular rows of dark pigment. The anal fin bears one to three vague dusky brown series of blotches on or adjacent to the rays. The pectoral fin is pigmented as in the male. The pelvic fins are colorless or have scattered melanophores.

The immaculate, slightly crenulate genital papilla of the female projects posteriorly to the base of the first anal spine, and is as long as or slightly longer than broad.

Coloration of juveniles.—Juveniles are generally more lightly pigmented than adults. The smallest individuals have moderately well-defined dorsal saddles and lateral blotches.

TABLE 6.
Squamation of nape in Etheostoma **ditrema** *and E. swaini (see text for explanation of symbols). Value for holotype in boldface.*

Species and drainage	Degree of nape squamation						
	0	**I**	II	III	IV	V	N
ditrema							
Chattooga	24	13	16	8	6	9	76
Etowah					1		1
Choccolocco	1	—	—	—	6	9	16
swaini							
Alabama	25	5	3	1	10		44

Infraspecific variation.—The single specimen of *E.* **ditrema** from the Etowah drainage of Georgia is apparently of the same genetic stock as specimens from the type locality in the Chattooga drainage. Members of the Choccolocco population differ markedly in several respects: they have the nape more often fully scaled (Table 6); the breast tends to be naked or weakly scaled; the females are darker and less mottled than Chattooga females, and more consistently possess an orange submarginal band in the spinous dorsal; the basicaudal dark spots occasionally are ocellate; the second anal spine is stronger. The most striking difference is that the Choccolocco population has a reduced number of dorsal rays. If a separation point in Table 4 is determined as being between 20 and 21 total dorsal rays, the average divergence between the Choccolocco population and the Etowah and Chattooga population is about 94 percent. Concurrently, the dorsal fin bases are more widely separated. These observations suggest that the number of dorsal fin rays has been secondarily reduced, and that the Choccolocco race is a derivative of a common stock which has been preserved in a more primitive state in the upper Coosa area.

The Choccolocco population likely represents a genetically valid subspecies, but we hesitate to designate it as such in view of the dearth of specimens and lack of knowledge of distribution of **ditrema** throughout the Coosa drainage. There may be a clinal type of variation in probable spring populations of the area surrounding the nearly 60 airline miles between Lyerly, Georgia and Coldwater, Alabama. In opposition to this view, Mr. Richard D. Caldwell of the University of Alabama informs us that *E.* **ditrema** was absent from numerous collections made by him in springs of northeastern Alabama.

Relationships.—The subgenus *Oligocephalus* retains in part the diversity of composition formerly possessed by the catch-all darter genus *Poecilichthys* (now a synonym of *Etheostoma* s.s.). Although evaluation of evolution within *Oligocephalus* is confused by many secondarily developed characters in the species, it is clear that *E.* **ditrema** is closely allied with the *E. asprigene* species group. Members of this group are *E. asprigene* (Forbes), *E. swaini*, *E.* **ditrema**, and an undescribed species from the Black Warrior-Tombigbee drainage in Alabama. These forms share the following characteristics; nuptial tubercles absent; opercular membranes overlapping or scarcely connected; body robust at the level of the spinous dorsal origin; supratemporal canal usually or frequently interrupted (much variation in *swaini and asprigene*); lateral line slightly to moderately arched anteriorly; humeral blotch not enlarged, inconspicuous or absent (usually distinct in *swaini*); color pattern of red-orange and blue or olive-green on the lower body, red-orange and blue in dorsal and anal fins of males; 35 to 39 vertebrae.

Collette (in press) has found the presence and distribution of breeding tubercles among percids to be of systematic significance. The

TABLE 7.
A comparison of Etheostoma **ditrema** *and E. swaini from the Alabama River basin.*

Character	Species	
	ditrema	*swaini*
Snout shape	Decurved, blunt	Produced, acute
Spinous dorsal fin	Spines slender, short; posterior edge gently curved and diagonal to body	Spines thicker, longer; posterior edge abruptly curved and nearly perpendicular to body
Greatest known size (s.l.)	42 mm	55 mm
Horizontal streaks on body	Absent or indistinct	Distinct
Dorsal saddles	Absent or indistinct	Distinct
Breast	Usually scaled	Naked
Prepectoral region	Exposed ctenoid scales	Naked or with embedded cycloid scales
Left pectoral rays	Mode at 12	Mode at 13
Coronal canal	Incomplete, usually 2 pores	Complete, a single pore
Lateral line contour	Moderately arched	Slightly arched
Pored lateral-line scales	19-35	31-43
Unpored lateral-line scales	13-30	4-12
Scales above lateral line	Mode at 4	Mode at 5

asprigene species group forms a natural group among atuberculate species of *Oligocephalus*. Others which appear most closely related are *E. exile* (Girard), *E. grahami*, *E. lepidum*, and *E. pottsi* (Girard). *Etheostoma mariae* (Fowler) and *E. juliae* Meek also lack tubercles, but on the basis of morphology and pigmentation do not appear as closely related to the *asprigene* group.

Etheostoma asprigene comprises a complex whose most easterly range along the Gulf Coast is in tributaries of the lower Mississippi River in Louisiana and Mississippi. *Etheostoma swaini* ranges from the Amite River drainage of Louisiana and Mississippi eastward below the fall line to the Apalachicola River drainage of Florida and Georgia (Bailey, Winn, and Smith, 1954).

Etheostoma **ditrema** appears to be a highly specialized derivative of *swaini* stock which early surmounted the fall line in the Coosa River system. The nature of the characters by which **ditrema** is distinct from *swaini* suggests that **ditrema** has diverged through genetic fixation of developmental traits which in darters are associated with neoteny. Collette (1962) discussed apparently neotenic populations of *E. (Hololepis) fusiforme* (Girard), which are characterized by reduction in adult size, decrease in relative number of pored lateral-line scales, and incomplete development of cephalic canals. All of these characters are found in **ditrema** as compared with *swaini*. Collette (1962) found reduction in development of the coronal canal in a neotenic population of *fusiforme*, but did not report as great a degree of reduction as that present in **ditrema**, in which the coronal branches usually do not fuse at all. The assemblage of characters in which *E.* **ditrema** seems a paedomorphic species have probably arisen through adaptation to the cold spring environment, to which the species presently appears restricted.

Other species of *Oligocephalus* inhabiting the Alabama River system include *E. parvipinne* and *E. whipplii artesiae* (Hay), which have the lateral line complete or nearly so, and possess moderately conjoined opercular membranes. *Etheostoma parvipinne* apparently occurs only on the Coastal Plain. *Etheostoma whipplii* occurs above and below the fall line, but has never been collected with **ditrema.**

Etheostoma **ditrema** resembles species of the subgenus *Hololepis* in the configuration of the lateral line. Two species of *Hololepis* are reported from the Alabama River system, including *E. fusiforme barratti* (Holbrook) and *E. zoniferum* (Hubbs and Cannon), and a third, *E. gracile* (Girard), is known from the Tombigbee River system (Collette, 1962). In the Mobile Bay system these occur only on the Coastal Plain. They differ from *E. ditrema* in possessing nuptial tubercles and in lacking red-orange body pigmentation in breeding males. The lateral line is more highly arched in *Hololepis* species. The moderately arched lateral line in E. **ditrema** seems to be a secondary specialization, and its similarity to that of *Hololepis* almost certainly represents convergence (probably as does the somewhat arched form of the lateral line in *E. exile*).

Etheostoma (Psychromaster) trisella Bailey and Richards is known from a unique specimen collected about midway between two of the known localities of **ditrema.** Repeated efforts by several groups to collect further specimens have been futile. Although the specimen is distinct in possessing a single weak anal spine, three intense dorsal saddles, and a complete lateral line, it is possible that the type of *trisella* is an aberrant hybrid between **ditrema** and another darter. This is rather tenuously suggested by the generally blotched color pattern, the overlapping opercular membranes, and presence of two coronal pores in *trisella* (which the authors mentioned was a probable anomaly, but which is the usual condition in **ditrema**), as well as its apparent absence in the region today. It is understandable that a large-stream form such as *E. (Nothonotus) acuticeps* Bailey might be collected only rarely, but all habitats (mainly springs and small streams) of the region in which *trisella* might occur have been surveyed intensively.

Habitat and life history.—*E.* **ditrema** has been collected recently only in or near large springs. We suspect that the "millponds" in which Jordan (1876) found specimens were springfed impoundments, as the region of Rome, Georgia has many large springs.

The spring at the type locality boiled from a bed of dolomitic limestone at a rate of about 30 cubic feet per second. The water was cold (16 to 18 C), colorless, and was clear even after heavy rains had roiled neigh-

boring streams. The bottom was composed of a deep bed of soft whitish clay overlaid by detritus and a dense growth of aquatic mosses (*Fontinalis filiformis* and *Fissidens debilis*). The greatest depth of water was about two meters. The spring pool was about 15 m in diameter, and was surrounded by brush and open woods. An abrupt break in habitat type occurred with the beginning of moderate flow at the head of the gravelly effluent stream, which was about 2 m wide and choked in place with submerged *Sparganium americanum*.

E. **ditrema** was the only darter present in the spring pool. It was always associated with dense aquatic vegetation, and individuals could occasionally be seen perching at the surface of moss clumps. It was most commonly captured in less than a meter of water, but was also taken as deep as 1.3 m.

Associated fish species in the spring pool at the Chattooga locality included *Esox americanus, E. niger, Minytrema melanops, Moxostoma duquesnei, Notropis chrosomus, N. lirus, Semotilus atromaculatus, Ictalurus melas, Lepomis cyanellus, Micropterus s. salmoides,* and *Cottus carolinae zopherus*. In the effluent stream, the above were taken (except for *E.* **ditrema**), as well as *Hypentelium etowanum, Campostoma anomalum, Notropis c. chrysocephalus, N. xaenocephalus, Rhinichthys atratulus, Lepomis m. megalotis, Micropterus coosae, Etheostoma (Ulocentra) coosae,* and *Percina caprodes carbonaria*.

As Coldwater Spring is the chief water supply for the city of Anniston, Alabama, we were forced to collect in Coldwater Creek just below the spring overflow. The spring flows from a thrust in the Weisner Quartzite formation, and yields 32 million gallons per day. The flow in Coldwater Creek was estimated at 100 cfs. The water was clear, colorless, and cold (18 C). *Etheostoma* **ditrema** was the only darter present, and was taken from dense silted patches of *Myriophyllum* growing in protected pockets along the left stream edge (right edge was polluted from a tributary a short distance below). Several specimens were captured in a muddy ditch near its junction with Coldwater Creek.

Associated species at the Coldwater locality were *Lampetra aepyptera, Esox americanus, E. niger, Gambusia affinis, Lepomis cyanellus, L. macrochirus,* and *Cottus carolinae zopherus*.

Jordan (1876) took *Notropis lirus, Etheostoma stigmaeum,* and *Percina n. nigrofasciata* with *E.* **ditrema.**

Males had assumed nuptial coloration by the end of April. They were still brightly colored in mid-July. It is probable that bright coloration is maintained year-round.

Females were gravid in collections made in April through July, but were largely spent by the latter date. Coldwater females were greatly swollen with eggs on June 1 (Fig. 3), but did not yield eggs when gently pressed. Ovarian eggs were large and few in number. Chattooga females had eggs of an average diameter of 1 mm on June 1, and 1.2 mm on June 23. One at 40.5 mm s.l. had 25 large ova in the left ovary and 19 in the right. Another at 33.1 mm had 23 (left) and 14 (right). A third at 31.7 mm had 23 ripe eggs in the right ovary. The smallest gravid female was 24.4 mm long.

The smallest young available (15.2 mm s.l.) was taken at the Chattooga locality on 18 July. Spawning likely occurs throughout the month of June.

The name *ditrema* refers to the typical possession of two coronal pores.

Literature Cited

Bailey, R. M., and W. A. Gosline. 1955. Variation and systematic significance of vertebral counts in the American fishes of the family Percidae. *Misc. Publ. Mus. Zool. Univ. Michigan* 93: 1-44.

....., and W. J. Richards. 1963. Status of *Poecilichthys hopkinsi* Fowler and *Etheostoma trisella*, new species, percid fishes from Alabama, Georgia, and South Carolina. *Occ. Pap. Mus. Zool. Univ. Michigan* 630: 1-21.

....., H. E. Winn, and C. L. Smith. 1954. Fishes from the Escambia River, Alabama and Florida, with ecologic and taxonomic notes. *Proc. Acad. Nat. Sci. Philadelphia* 106: 109-164.

Collette, B. B. 1962. The swamp darters of the subgenus *Hololepis* (Pisces, Percidae). *Tulane Stud. Zool.* 9(4): 115-211.

.....In press. The systematic significance of breeding tubercles in fishes of the family Percidae. *Proc. U. S. National Mus.*

....., and R. W. Yerger. 1962. The American percid fishes of the subgenus *Villora*. *Tulane Stud. Zool.* 9(4): 213-230.

Distler, D. A., and A. L. Metcalf. 1962. *Ethcostoma pallididorsum*, a new percid fish from the Caddo River system of Arkansas. *Copeia* 1962(3): 556-561.

Hubbs, C. L., and M. D. Cannon. 1935. The darters of the genera *Hololepis and Villora*. *Misc. Publ. Mus. Zool. Univ. Michigan* 30: 1-93, 3 pl.

_____, and K. F. Lagler. 1958. Fishes of the Great Lakes region. *Cranbrook Inst. Sci. Bull.* 26: 1-213, 44 pls., 251 figs.

Jordan, D. S. 1876. A partial synopsis of the fishes of upper Georgia. *Ann. Lyc. Nat. Hist. N.Y.* 11: 307-377.

Kuehne, R. A., and R. M. Bailey. 1961. Stream capture and distribution of the percid fish *Ethcostoma sagitta*, with geologic and taxonomic considerations. *Copeia* 1961(1): 1-8.

Strawn, K., and C. Hubbs. 1956. Observations on stripping small fishes for experimental purposes. *Copeia* 1956(2): 114-116.

Yerger, R. W. 1960. *Ethcostoma okaloosae* (Fowler), a percid fish endemic in northwest Florida. *Bull. Assoc. Southeastern Biol.* 7(2): 41 (abstract).

June 23, 1965

PARASITES FROM LOUISIANA CRAYFISHES

FRANKLIN SOGANDARES-BERNAL,

Department of Zoology,
Tulane University,
New Orleans, Louisiana

Abstract

Two microsporidians, *Thelohania* sp. and *? Plistophora* sp., and eight trematodes, *Crepidostomum cornutum*, *Gorgodera amplicava*, *Microphallus opacus*, *M. progeneticus*, *Maritrema obstipum*, *Macroderoides typicus*, *Ochetosoma* sp., and *Paragonimus kellicotti*, are reported from crayfishes in Louisiana. The presence of the metacercariae of *P. kellicotti* is of particular interest since the crayfishes in which this parasite is found are eaten by humans in Louisiana.

Introduction

Nine species of crayfishes have been examined for parasites during studies of paragonimiasis in Louisiana from 1959-1964.

Method of Procedure

Crayfishes were collected by the most expedient methods and usually transported to my laboratory for examination. The live specimens were usually identified by the late Doctor G. H. Penn, Department of Zoology, Tulane University, or identified with the aid of a key by Penn (1959). The crayfishes were kept in aquaria or fingerbowls until they were decapitated and examined. The muscles and internal organs were separated and carefully teased apart with dissection needles while viewed through a binocular stereoscopic microscope. Most parasites were studied alive under a binocular compound microscope. Specimens not discarded were fixed in Alcohol-Formalin-Acetic solution, stained in Van Cleave's Combination Hematoxylin (Van Cleave, 1953), and mounted in Permount (Fisher Sci. Co., N. Y.). The parish of each locality is mentioned the first time the locality is cited in the text.

* Supported in part by a research grant (AI 03386 TMP) from the National Institutes of Health.

Findings

Protozoa

Microsporidia, Nosematidae

1. *Thelohania* sp.
(Figs. 1-4)

Host: Cambarellus shufeldti (Faxon, 1881)

Location: Body musculature

Localities: Chacahoula (Terrebonne Par.) and near Covington (St. Tammany Par.), Louisiana

Discussion: Sogandares (1962a) reported this *Thelohania* sp. from a *C. shufeldti* collected at Chacahoula, Louisiana. Since that time several additional natural infections have been found in the same host species near Covington, Louisiana. Sogandares (1962a) believed his record to be the first for a microsporidian in North American crayfishes. This belief was in error, since Sprague (1950) named in an abstract, *Thelohania cambari* from *Cambarus bartoni* from streams along the Georgia-North Carolina border. He reported that the sporont (pansporoblast of other authors) of *T. cambari* gave rise to eight spores which averaged 4.6 microns long by 2.2 microns in greatest width, were somewhat oval in shape, being broadly rounded at both extremities, tapered slightly from anterior to posterior, and lacked a persistent sporont membrane.

Editorial Committee for this Paper:

Horton H. Hobbs, Jr., Senior Research Scientist, Department of Zoology, U. S. National Museum, Washington, D. C.

Harold W. Manter, Professor of Zoology, University of Nebraska, Lincoln, Nebraska

Mary Hanson Pritchard, Research Associate, Department of Zoology and Physiology, University of Nebraska, Lincoln, Nebraska

The polar filament was reported to be 80-90 microns long.

Thelohania sp. from *Cambarellus shufeldti* had pansporoblasts 6-9 microns in diameter, which as a preterminal product contained eight sporoblasts. Each sporoblast formed one spore, resulting in eight spores surrounded by the pansporoblast membrane. Live spores measured from 3.0 to 3.5 microns long by 1.2 to 1.6 microns wide. Polar filaments about 15 microns long observed in 3 spores were in all probability only partially extruded.

The Louisiana *Thelohania* from *C. shufeldti* probably represents a different species from *T. cambari* since the spores differ in size and the pansporoblast membrane of the former is persistent. *Thelohania contejeani* Henneguy and Thelohan, 1892, the only European species of *Thelohania* from crayfishes, has a spore 2 to 3 microns long. Thus, *T.* sp. from Louisiana has spores which are intermediate in size between more of *T. cambari* and *T. contejeani.* The specific identity of the Louisiana *Thelohania* from *C. shufeldti* awaits information regarding the filament length and life-history, but low incidence of natural infection makes the necessary study difficult to complete.

2. ? *Plistophora* sp.

(Figs. 5-6)

Host: Cambarellus puer Hobbs, 1945

Location: Body musculature

Locality: Near Covington, Louisiana

Discussion: Sogandares (1962a) reported this form from one *C. puer.* This species is characterized by 19 to 21 comma-shaped spores, about 6.0 to 9.0 microns long by 4 microns wide, contained in the pansporoblast membrane. I have not collected this species again.

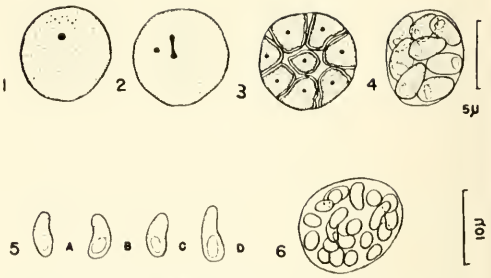
Platyhelminthes
Trematoda, Digenea
Allocreadiidae

3. *Crepidostomum cornutum* (Osborn, 1903) Stafford, 1904

(Fig. 7)

Hosts: Cambarellus puer Hobbs, 1945; *C. shufeldti* (Faxon, 1881); *Orconectes lancifer* (Hagen, 1870); *Procambarus clarkii* (Girard, 1852); *P. blandingi acutus* (Girard, 1852); *P. penni* Hobbs, 1951

Location: Hepatopancreas, heart, pericardial membranes and musculature of cephalothorax.



Figures 1-6. *Microsporidians.* **1-3.** *Thelohania* sp., developing pansporoblasts; **4.** same, pansporoblast membrane surrounding spores; **5A, B, C, D,** *?Plistophora* sp. variation in shape and size of spores; **6.** same, pansporoblast membrane surrounding spores. [Courtesy Journal of Parasitology 48(3): 493]

Localities: C. puer, C. shufeldti, and *O. lancifer* from Gibson (Terrebonne Par.) and Maringouin (Iberville Par.); *P. clarkii* from Gibson, Ama, Bonnet Carre Spillway (St. Charles Par.), Sarpy (St. Charles Par.), Amite River on U. S. Hwy. 190 (East Baton Rouge Par.), Maringouin, Bayou close to Rosedale on La. Hwy. 76 (West Baton Rouge Par.), 1.7 mi. N. Junction La. Hwy. 20 on La. Hwy. 309 (Terrebonne Par.); *P. blandingi acutus* from Amite River on U. S. Hwy. 190; *P. penni* from near Pineville (Rapides Par.); all Loiusiana localities.

Discussion: C. cornutum is without doubt one of the most common and widespread trematodes found encysted in Louisiana crayfishes. Hopkins (1934) reported this species from crayfishes (listed as *Cambarus* sp. from Baton Rouge, *Amphiuma means* Cuvier, "catfish," and *Ictalurus melas* (Rafinesque) (=*Ameiurus melas*) in Louisiana. Stafford (1931) reported this species from *Cambarus* spp. in the neighboring state of Mississippi. The crayfishes reported by Hopkins (1931) and Stafford (1931) cannot be identified because at that time most North American crayfishes were assigned to the genus *Cambarus.*

Hopkins (1934) and Ameel (1937) both observed that encysted metacercariae of *C. cornutum* produced eggs. I observed such progenesis frequently in my specimen of *C. cornutum* from Louisiana. It is really not known if these eggs are the result of parthenogenesis or self-matings, or if the re-

sultant developmental stages are capable of continuing with their normal biological functions of reproduction.

One first intermediate host of *C. cornutum* in Louisiana is a sphaeriid clam of the genus *Musculium*. Naturally infected sphaeriids have been collected at Gibson and at a bayou near Rosedale at the junction of La. Hwys. 76 and 413. Cercariae from clams of both localities readily encysted on the surface of the heart and hepatopancreas of laboratory reared *P. clarkii* and *C. shufeldti*, lightly encysted matacercariae being found as early as 16 hours postexposure.

Natural definitive hosts of *C. cornutum* found in this study were *Amia calva* Linn. and *Lepomis macrochirus* (Rafinesque). Other hosts in Louisiana have been cited above.

Gorgoderidae

4. *Gorgodera amplicava* Looss, 1899

(Figs. 8-10)

Hosts: Orconectes palmeri creolanus (Creaser, 1933), *Procambarus clarkii* (Girard, 1852)

Location: On lower quadrant of stomach wall, usually at level of gastric mill

Localities: O. palmeri creolanus from stream drainage into Bayou Sarah, about 1 mile S. Mississippi State Line (West Feliciana Par.); *P. clarkii* from Ama, Bonnet Carre Spillway, Sarpy, Maringouin, Edgard (Lafourche Par.), Buras (Plaquemines Par.), Pierre Pass (Assumption Par.), Venice (Plaquemines Par.), and 1.7 mi. N. Jct. La. Hwy. 20 on La. Hwy. 309.

Discussion: Krull (1935) described the life cycle of this species. The partial life-cycle of *G. amplicava* has been experimentally established in this laboratory in young *Rana clamitans* Latreille and adult *Amphiuma means* Cuvier. *Rana catesbeiana* Shaw is one definitive natural host of *G. amplicava* in Louisiana, and has been shown by Penn (1950) to feed on crayfishes. *Hyla cinerea* (Schneider) and *Chaenobryttus gulosus* (Cuv. & Val.) were refractory to infection. Judging from the site of encystment, I suspect that crayfishes become infected by ingesting the cercariae. Almost all crayfishes collected in Sarpy, an oil field near Norco, Louisiana, were infected with *G. amplicava.* The species has been previously reported from crayfishes by Krull (1936).

Microphallidae

5. *Microphallus opacus* (Ward, 1894) Ward, 1901

(Figs. 11-13)

Host: Cambarellus puer Hobbs, 1945 and *Procambarus clarkii* (Girard, 1852)

Location: Hepatopancreas

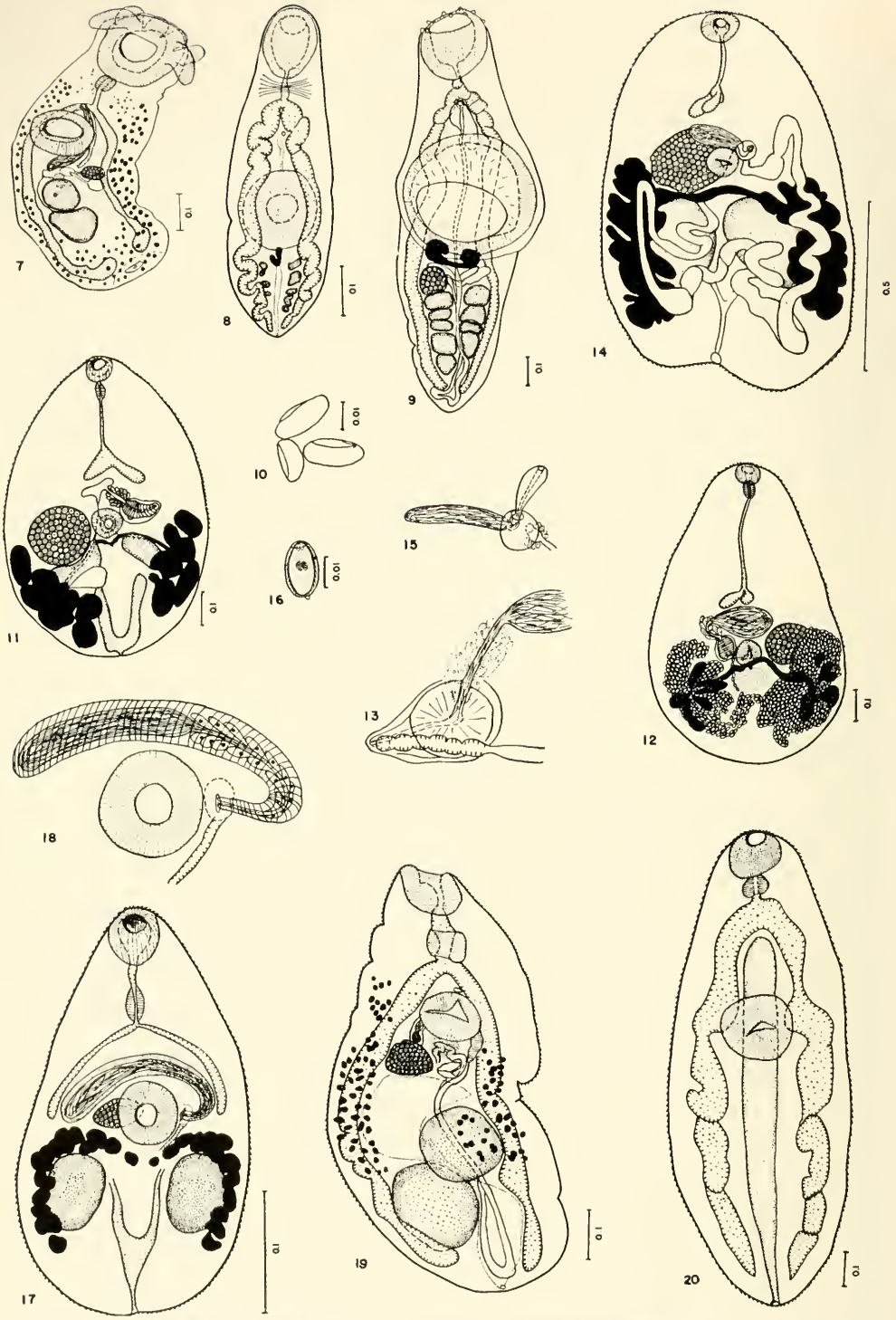
Locality: Bayou close to Rosedale on La. Hwy. 76.

Discussion: M. opacus was the most common metacercaria in *P. clarkii* at the Rosedale locality, being found in about 98% of those examined. *Amnicola,* probably *integra,* from the same locality released three different types of microphallid cercariae, probably corresponding with the 3 microphallid tremadoes encysted in crayfishes from the same bayou.

Encysted specimens of *M. opacus* were injected under the cephalothorax of *P. clarkii* and *C. puer* from uninfected localities, but these worms did not produce eggs, even after three weeks, though they did remain alive for this period of time. CF_1 white mice were fed cysts of *M. opacus* and gravid specimens were recovered after 24 hours. The reservoirs for the adults of *M. opacus* in the Rosedale locality are unknown, though the species will develop to maturity in a number of vertebrates (Rausch, 1947).

In this laboratory *M. opacus* would produce eggs in 0.85% NaCl-1:20,000 Streptomycin sulfate solution in 12 to 36 hours at 30 C. Metacercariae were artificially excysted by vigorously shaking and incubating the entire infected crayfish hepatopancreas in a pepsin-HCl solution (100 ml. 0.3% HCl and 40 ml. 0.5% pepsin N.F.) at 40 C for 30 minutes, then incubating the washed cysts (0.85% NaCl) in a trypsin solution (0.5% trypsin in 0.85% NaCl, adjusted to pH 7.8 with K_2HPO_4) held at 40 C for 10-12 min. The excysted metacercariae were then washed in 30 C 0.85% NaCl-1:20,000 Streptomycin sulfate solution and later incubated in the same but clean solution. Thousands of clean excysted metacercariae could be obtained by following the above method.

Rausch (1947) observed that when metacercariae of *M. opacus* were left in crayfish hepatopancreas extract overnight at room temperatures they excysted, found partners and began to mate. Ward (1900) also observed worms from natural infections *in*



Figures 7-20. *Digenetic Trematodes.* **7.** *Crepidostomum cornutum,* excysted metacercaria; **8.** *Gorgodera amplicava,* excysted metacercaria; **9.** same, adult from experimental infection of *Amphiuma;* **10.** same, eggs; **11.** *Microphallus opacus;* excysted metacercaria; **12.** same, adult from experimental infection of CF_1 mouse; **13.** same, dorsal view of terminal genitalia; **14.** *Microphallus progeneticus,* adult from *Cambarellus puer;* **15.** same, terminal genitalia; **16.** same, egg containing miracidium; **17.** *Maritrema obstipum,* excysted metacercaria; **18.** same, terminal genitalia; **19.** *Macroderoides typicus,* excysted metacercaria; **20.** *Paragonimus kellicotti,* excysted metacercaria. The projected scales have their values indicated in millimeters. All figures accompanied by a projected scale were drawn with the aid of a Leitz camera lucida for inclined microscopes. Those figures lacking a scale are sketches.

copula. In several experiments in this laboratory, encysted metacercaries from post-pepsin-HCl treatment were individually isolated and incubated in trypsin-saline solution. The resulting excysted worms, which had not been able to mate with a partner, were individually isolated in 4 x 40 mm tubes containing NaCl-Streptomycin solution and kept at room temperature. Approximately 11% of the single worms treated as indicated above produced eggs of unascertained viability. By following almost the same procedure in another experiment, 50 pairs of excysted *M. opacus* metacercariae were placed in identical tubes (2 worms per tube) and solutions. Eighty-four *percent* of these worms produced eggs, the viability of which was not determined. Further experimentation on this aspect has not been continued since a severe drought in 1963 decimated the snail and crayfish populations. At present it is not known if mating is always necessary for the production of viable eggs, nor is it known if temperature or possible increase in titer of materials released by the mated pairs was responsible for egg production. Ching (1963a), for example, has indicated that increased (30 to 40 C) temperature stimulated egg production in *Levenseniella charadriformis* Young, 1949. In another experiment (Ching, 1963b), she did not observe egg production of another microphallid, *Maritrema laricola* Ching, 1963, when held at 30 to 40 C. The viability of the eggs of the former species was not tested. Experiments of this type are necessary to answer certain questions of interest to trematode specialists. For example: Are eggs from isolated worms a result of parthenogenesis or self-fertilization? Are the developmental stages of eggs produced by "self-matings" viable throughout their life-cycles? If self-matings are possible, what is the statistical significance of such self-matings on the species population structure?

6. *Microphallus progeneticus* Sogandares, 1962

(Figs. 14-16)

Host: Cambarellus puer Hobbs, 1945, *Procambarus clarkii* (Girard, 1852)

Location: Cephalothoracic cavity

Locality: Gibson, Maringouin, Bayou close to Rosedale on La. Hwy. 76, Louisiana.

Discussion: This species, first found by Dr. Joseph Fitzpatrick, then a graduate student and assistant in my laboratory, was described by Sogandares (1962b). It is unique in lacking a complete pharynx and may be gravid when unencysted and wandering over the organs of the cephalothorax of the affected hosts. Eggs *in utero* contain actively moving miracidia.

Live specimens of *Microphallus progeneticus* were intubated *per ora* into several CF_1 laboratory mice, but none were recovered upon necropsy after 24 hours. The worms presumably were passed or digested by the host mice. *M. progeneticus,* except for the lack of a pharynx, is close to *M. opacus,* and may represent a sibling species of the latter. However, *M. opacus* is encysted and *M. progeneticus* is free in the crayfish hosts. Even if *M. opacus* could excyst in a crayfish host under certain conditions, which seems unlikely, excysted specimens experimentally introduced into the hemocoels of crayfishes failed to mature in three weeks, (see under *M. opacus*), though maturation took place in CF_1 laboratory mice and *in vitro.* It seems unlikely that gene flow between the two forms could occur even if both were ingested by a single vertebrate host.

7. *Maritrema obstipum* (Van Cleave and Mueller, 1932) Mueller, 1934

(Figs. 17-18)

Host: Cambarellus shufeldti (Faxon, 1881) and *Procambarus clarkii* (Girard, 1852)

Location: Central shaft of gill filaments and hepatopancreas

Locality: Bayou close to Rosedale on La. Hwy. 76, Louisiana

Discussion: This species was first observed by me in the gill filaments of its hosts. Later, great numbers were easily recovered from the hepatopancreas of affected hosts with the excystment procedure described under *Microphallus opacus.* Etges (1953) studied the life-history of *Maritrema obstipum* and found it encysted in the isopod *Asellus communis.* His identification of *Maritrema obstipum* seems doubtful at present, and completion of the life-history of the forms from crayfishes may elucidate the identity of his species. The first intermediate host reported by Etges (1953) was *Amnicola pilsbryi.* One of the three microphallid cercariae from *Amnicola,* reported under

Microphallus opacus, is probably the larva of this species. Stafford (1931) reported a *Maritrema* sp. from *Cambarus* in Mississippi.

Plagiorchiidae

8. *Macroderoides typicus* (Winfield, 1929) Van Cleave and Mueller, 1932

(Fig. 19)

Hosts: Procambarus blandingi acutus (Girard, 1852) *P. clarkii* (Girard, 1952), and *Orconectes lancifer* (Hagen, 1870)

Location: Cephalothoracic and antennal musculature

Localties: P. blandingi acutus and *P. clarkii* from Edgard, *P. clarkii* from Bayou near junction of La. Hwys. 413 and 76 (West Baton Rouge Par.), and *O. lancifer* from Gibson, Louisiana.

Discussion: Macroderoides typicus also utilizes tadpoles as second intermediate hosts (McMullen, 1935). The cercaria emerges from *Helisoma trivolvis lentum* in Louisiana. Adults of *M. typicus* have been found in *Amia calva* Linn. from Louisiana. Exposure of various species of sunfishes to cysts of *M. typicus* produced negative results.

9. *Ochetosoma* sp.

Host: P. clarkii (Girard, 1852)

Location: Abdominal musculature

Locality: Bayou close to Rosedale on La. Hwy. 76, Louisiana

Discussion: Adult hosts of *Ochetosoma* in Louisiana are usually snakes of the genera *Natrix* and *Agkistrodon.* Certain species of Louisiana *Ochetosoma* are known to utilize physid snails and tadpoles as intermediate hosts (Byrd, 1935). Physids, tadpoles, and watersnakes were present in the locality in which the crayfishes were found infected with *Ochetosoma.* Penn (1950) has indicated that certain watersnakes feed heavily on crayfishes. Ninety-seven of 100 crayfishes from the locality were found infected with *Ochetosoma.*

Troglotrematidae

10. *Paragonimus kellicotti* Ward, 1908

(Fig. 20)

Hosts: Procambarus blandingi acutus (Girard, 1852) and *P. clarkii* (Girard, 1852)

Location: Heart and surrounding membranes

Locality: Amite River on U. S. Hwy. 190

Discussion: My colleague, Dr. E. A. Malek, and I first collected this species in crayfishes. Experimental infections have been established in his and my laboratories, and a separate paper describing our results is in preparation.

Summary

Parasites found in Louisiana crayfishes during this study are listed in Table 1. All localities visited for collection of crayfishes are indicated in Figure 21. Localities from which infected crayfishes were taken are indicated, under the specific parasite being considered, in the text. Where possible, local, experimental, and natural intermediate and definitive hosts of parasites discussed are cited in the text.

The parasites found inhabiting crayfishes in Louisiana are represented by two microsporidians of the Nosematidae, and 8 digenetic trematodes by one species of Allocreadiidae, one species of Gorgoderidae, three species of Microphallidae, two species of Plagiorchiidae, and one species of Troglotrematidae.

The presence of *Paragonimus kellicotti,* the North American mammalian lung fluke, is of particular interest since the specific hosts in which this parasite was found are utilized as food by humans in Louisiana.

Figure 21. Map showing collecting localities in Louisiana. Areas visited are indicated by dark circles.

Host-Parasite Index

Cambarellus puer
- *Crepidostomum cornutum*
- *Microphallus opacus*
- *Microphallus progeneticus*
- *?Plistophora* sp.

Cambarellus shufeldti
- *Crepidostamum cornutum*
- *Maritrema obstipum*
- *Thelohania* sp.

Orconectes clypeatus (Hay, 1899)
- Negative

Orconectes lancifer
- *Crepidostomum cornutum*
- *Macroderoides typicus*

Orconectes palmeri creolanus
- *Gorgodera ampuicava*

Procambarus clarkii
- *Crepidostomum cornutum*
- *Gorgodera amplicava*
- *Macroderoides typicus*
- *Maritrema obstipum*
- *Microphallus opacus*
- *Microphallus progeneticus*
- *Ochetosoma* sp.
- *Paragonimus kellicotti*

Procambarus blandingi acutus
- *Crepidostomum cornutum*
- *Macroderoides typicus*
- *Paragonimus kellicotti*

Procambarus penni
- *Crepidostomum cornutum*

Procambarus vioscai (Penn, 1946)
- Negative

Literature Cited

Ameel, Donald J. 1937. The life history of *Crepidostomum cornutum* (Osborn). *J. Parasitol.* 23: 218-220.

Byrd, Elon E. 1935. Life history studies of Reniferinae (Trematoda, Digenea) parasitic in Reptilia of the New Orleans area. *Trans. Am. Microscop. Soc.* 54: 196-225.

Ching, Hilda Lei 1963a. The life cycle and bionomics of *Levenseniella charadriformis* Young, 1949 (Trematoda: Microphallidae). *Canad. J. Zool.* 41: 889-899.

———— 1963b. The description and life cycle of *Maritrema laricola* sp. n. (Trematoda: Microphallidae) *Canad. J. Zool.* 41: 881-888.

Etges, Frank J. 1953. Studies on the life histories of *Maritrema obstipum* (Van Cleave and Mueller, 1932) and *Levenseniella amnicolae* n. sp. (Trematoda: Microphallidae). *J. Parasitol.* 39: 643-662.

Hopkins, Sewell Hepburn 1934. The papillose Allocreadiidae. *Ill. Biol. Monogr.* 13: 45-124.

Krull, Wendell H. 1935. Studies on the life history of a frog bladder fluke, *Gorgodera amplicava* Looss, 1899. *Pap. Mich. Acad. Arts & Letters* 20:697-710.

———— . 1936. Additional second intermediate hosts for *Gorgodera amplicava* Looss, 1899. *Proc. Helm. Soc. Wash.* 3: 58.

McMullen, Donald B. 1935. The life history and classification of two allocreadiid like plagiorchids from fish, *Macroderoides* typicus (Winfield) and *Alloglossidium corti* (Lamont). *J. Parasitol.* 21: 369-380.

Penn, George Henry 1950. Utilization of crawfishes by cold-blooded vertebrates in the Eastern United States. *Am. Midl. Nat.* 44: 643-658.

———— 1959. An illustrated key to the crawfishes of Louisiana with a summary of their distribution within the state (Decapoda: Astacidae). *Tulane Stud. Zool.* 7: 3-20.

Rausch, Robert 1947. Some observations on the host relationships of *Microphallus opacus* (Ward, 1894). *Trans. Am. Microscop. Soc.* 66: 59-63.

Sogandares-Bernal, Franklin 1962a. Presumable microsporidiosis in the dwarf crayfishes *Cambarellus puer* Hobbs and *C. shufeldti* (Faxon) in Louisiana. *J. Parasitol.* 48: 493.

———— 1962b. *Microphallus progeneticus*, a new apharyngeate progenetic trematode (Microphallidae) from the dwarf crayfish, *Cambarellus puer*, in Louisiana. *Tulane Stud. Zool.* 9: 319-322.

Sprague, Victor 1950. *Thelohania cambari* n. sp., a microsporidian parasite of North American crayfish. *J. Parasitol.* 36 (Sec 2): 46.

Stafford, E. W. 1931. Platyhelmia insects and crustacea. *J. Parasitol.* 18:131.

Van Cleave, Harley J. 1953. Acanthocephala of North American Mammals. *Ill. Biol. Monogr.* 23: 1-179.

Ward, Henry B. 1900. Notes on the parasites of the lake fish III. On the structure of the copulatory organs in *Microphallus* nov. gen. *Trans. Am. Microscop. Soc.* 22: 175-187, 5 figs.

A NEW SUBSPECIES OF THE CRAWFISH *ORCONECTES LEPTOGONOPODUS* FROM THE OUACHITA RIVER DRAINAGE IN ARKANSAS

J. F. FITZPATRICK, JR.,

Department of Biology,
University of Virginia,
Charlottesville[1]

ABSTRACT

A new subspecies of the crawfish *Orconectes leptogonopodus* Hobbs, *O. l.* **acares**, is described from the Ouachita River drainage in Arkansas. The new race is distinguished from the typical subspecies by shorter terminal elements of the first pleopod, a shorter pleopod, and other minor differences. *Orconectes leptogonopodus leptogonopodus* is recorded from Oklahoma.

An excellent series of *Orconectes leptogonopodus* Hobbs (1948) was found among Tulane University lots of Ozark-Ouachita crawfishes sent to me for identification by Dr. George H. Penn shortly before his death. About the same time Dr. Horton H. Hobbs, Jr., of the United States National Museum sent an "interesting" series of the species collected by Dr. A. P. Blair from the Caddo River drainage. Examination of this large series revealed that Ouachita River populations of *O. leptogonopodus* are morphologically distinct from the topotypic popularion of *O. leptogonopodus* and from other populations located in tributaries of the Red River. Accordingly, the Ouachita populations are recognized as subspecifically different from the Red River populations of *O. leptogonopodus* and a new subspecies is described.

In addition to the persons mentioned above, the writer is indebted to Dr. Alfred E. Smalley of Tulane University who has permitted the selection of type material to be distributed as noted below.

The name of this new subspecies is taken from the Greek, *acares,* short; it is so named because a prominent characteristic is the short, in comparison with *l. leptogonopodus,* terminal elements of the first pleopod.

ORCONECTES LEPTOGONOPODUS **ACARES,** *subsp. nov.*

Synonymy.

Orconectes leptogonopodus Williams, 1954 *(in partim).*

Diagnosis: Pigmented; eyes normal. Rostrum with marginal tubercles or spines, median carina present, margins subparallel or slightly converging cephalad, not thickened; length of areola 29.1 to 33.7 (mean 31.8) per cent of total length of carapace, 5.5 to 7.0 times longer than broad, three to five punctations in narrowest part. Postorbital ridges strong, terminating cephalad in strong, divergent, corneous spines or tubercles; sides of carapace lacking lateral spines. First pleopod of first form male reaching caudal margin of coxopodite of first pereiopod with abdomen flexed; central projection with strong cephalic shoulder near base; central projection straight, longer than mesial process [ratio of central projection length to mesial process length 1.25 to 1.54 (mean 1.34)], slender, with tip curving caudodistally; mesial process straight, setiform, slender, delicate; tips of first pleopod divergent (Figs. A, E). Annulus ven-

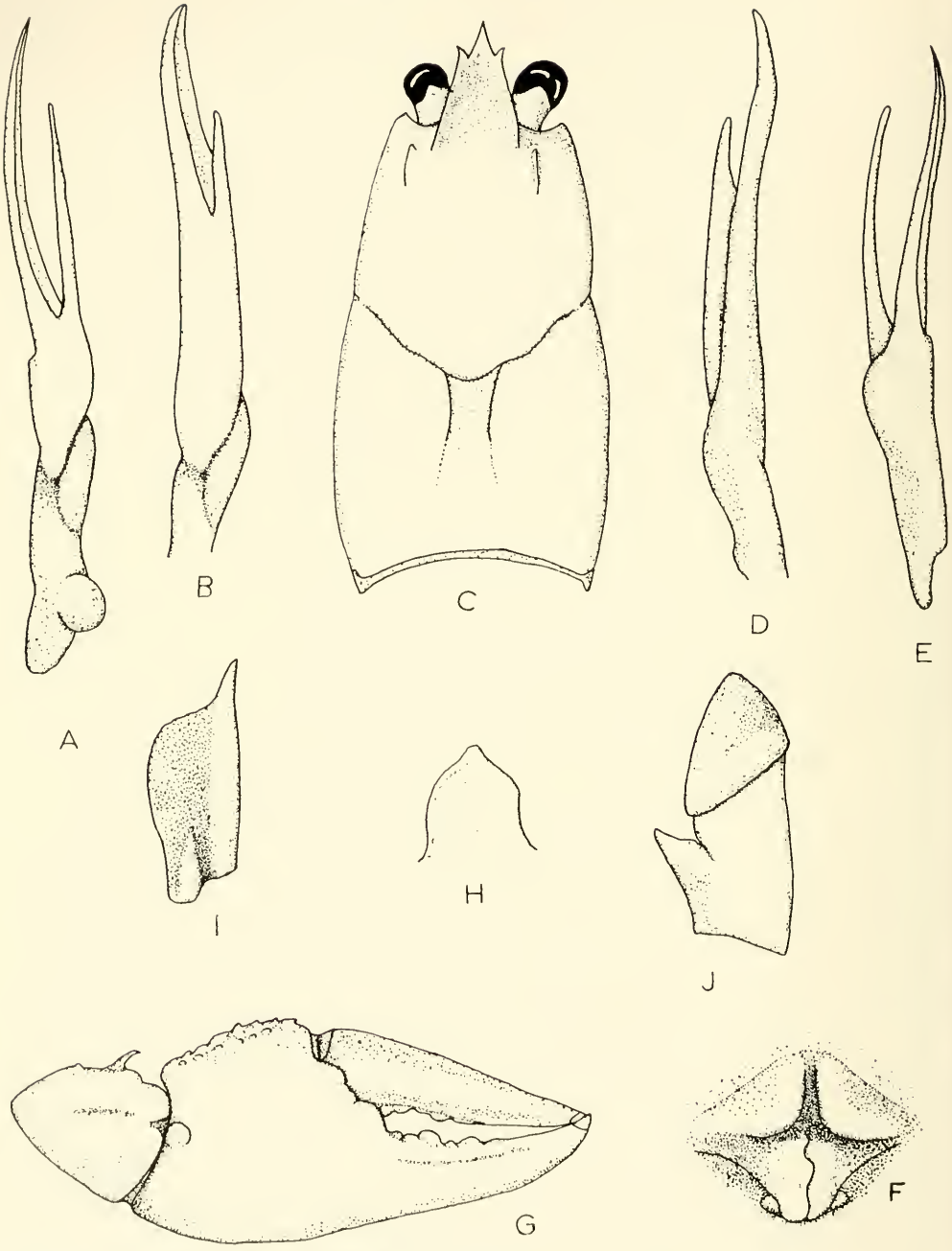
[1] Present Address: Department of Zoology, Mississippi State University, State College, Mississippi.

EDITORIAL COMMITTEE FOR THIS PAPER:

HORTON H. HOBBS, JR., Senior Scientist, Department of Zoology, United States National Museum, Washington, D. C.

ALFRED E. SMALLEY, Assistant Professor of Zoology, Tulane University, New Orleans, Louisiana

AUSTIN B. WILLIAMS, Professor of Zoology, University of North Carolina Institute for Fisheries Research, Morehead City, North Carolina



Figures A-J. *Orconectes leptogonopodus* **acares.**
Legend. **A.** Mesial view of first pleopod of holotype; **B.** Mesial view of first pleopod of morphotype; **C.** Dorsal view of carapace of holotype; **D.** Lateral view of first pleopod of morphotype; **E.** Lateral view of first pleopod of holotype; **F.** Annulus ventralis of allotype; **G.** Right chela of holotype, upper view; **H.** Epistoma of holotype; **I.** Antennal scale of holotype; **J.** Basipodite and ischiopodite of third pereiopod showing hook. (Mesial process of holotype slightly warped in preservation; in life, it is less divergent and is straight.)

tralis immovable, subrhomboid in outline, with prominent tongue-like caudal projection, deep transverse trough in anterior half; sinus originating in trough, winding sinuously either sinistrally or dextrally, disappearing in caudal margin (Fig. F).

Holotypic male, Form I: Body subcylindrical, slightly depressed. Abdomen narrower than cephalothorax (8.5, 8.7 mm in widest parts, respectively). Width of carapace greater than depth in region of caudodorsal margin of cervical groove (8.7, 6.9 mm).

Areola moderately broad (6.8 times longer than wide) with two or three punctations across narrowest part. Cephalic section of carapace about 1.9 times as long as areola. Length of areola 34.3 per cent of entire length of carapace. Dorsal features of carapace illustrated in Figure C.

Rostrum with slightly converging margins; margins not distinctly thickened, but terminating cephalically in strong spines; upper surface deeply concave, bearing setiferous punctations, and with a moderately developed median carina. Acumen short, broad; extending to distal end of peduncle of antennule; tip not upturned. Subrostral ridges evident in dorsal aspect for a short distance at bases.

Postorbital ridges strong, grooved dorsolaterally, projecting cephalad in strong divergent spines. Suborbital angle acute. Branchiostegal spines acute. Carapace with a weakly developed tubercle on each lateral surface at level of branchiocervical groove. Entire carapace studded with setiferous punctations except extreme cephalolateral ventral portions which bear setiferous granulations.

Abdomen shorter than carapace (17.2, 17.8 mm). Cephalic section of telson with two spines in each caudolateral corner.

Epistome (Fig. H) subcircular in outline with cephalomedian tubercle.

Antennules of usual form with prominent spine on ventral surface of basal segment. Antennae broken, but appear to have extended to posterior region of abdomen. Antennal scale (Fig. I) about 2.2 times longer than broad, mesial margin of lamellar portion evenly rounded, widest distal to midlength.

Chela (Fig. G) depressed, palm inflated; all surfaces bearing setiferous punctations. Tubercle present on lower surface of palm at base of dactyl. Inner margin of palm with two irregular rows of tubercles, lower row of seven and upper row of six. Fingers with slight gap at base. Upper surface of immovable finger with broad, rounded, submedian, longitudinal ridge flanked by setiferous punctations; another ridge along proximal three-fourths of finger immediately mesial to aforementioned ridge. Outer margin of immovable finger with well-defined keel extending proximally two-thirds length of palm; opposable margin of finger with row of two small, one large, and three small tubercles (proximal to distal) etxending along basal two-thirds and crowded minute denticles along distal one-third; submedian longitudinal ridge on lower surface of finger. Dactyl similar to immovable finger above and below; mesial margin with double row of tubercles along proximal one-third, lower row of three but upper row with only one well-defined tubercle; opposable margin with five small tubercles along basal two-thirds and crowded minute denticles in distal one-third.

Carpus of cheliped longer than broad and with broad shallow longitudinal furrow above; setiferous punctations over entire surface and few small tubercles on upper surface mesial to furrow; mesial surface with prominent tubercle on upper proximal one-third, strong acute spine on lower middle one-third, and tubercle on upper mesiodistal margin; lower submedian distal margin and lower laterodistal margin each with strong spine. Upper and lower surfaces of merus with scattered setiferous punctations; lateral surfaces generally smooth; three spines in line on upper distal surface; lower mesial surface with row of nine tubercles increasing in size distally, terminating in strong acute distal spine; single acute distal spine on lower laterodistal margin and row of one spine and nine tubercles proximal to distal spine. Lower surface of ischiopodite with small rounded tubercle. Hooks on ischiopodites of third pereiopods only (Fig. J); hooks simple.

First pleopod extending cephalad to caudal margin of coxa of first pereiopod with abdomen flexed. Tip terminating in two distinct parts, both slender and setiform; rami separated for considerable distance from tips and moderately divergent (Figs. A, E). Central projection corneous, straight, but with tip curved caudodistally. Mesial process not

extending so far distad as central projection, non-corneous, and quite delicate. (Delicate nature of mesial process results in preservation artifacts; so noted in figure of holotype.) Pleopods symmetrical (*sensu* Hobbs, 1962).

Morphotypic male, Form II: Differs from holotype in following respects: lateral tubercles of cephalothorax lacking. Carpus of cheliped with upper mesiodistal spine. Palm less inflated and proportionately smaller than holotype. Hooks on ischipodites of third pereiopods much reduced. Both elements of pleopod (Figs. B, D) non-corneous, blunter and in close apposition along basal three-fourths.

Allotypic female: Differs from holotype in following respects: palm proportionately smaller and less inflated than holotype. First pleopod biramous and weakly developed.

Annulus ventralis immovable, subrhomboid in outline with prominent tongue-like projection of caudal margin, fused cephalically with sternum but with two prominent lateral tubercles raised (ventrally) in cephalic half. Deep transverse trough in cephalic half, with aforementioned tubercles overhanging cephalolateral portions. Sinus originating in trough, curving gently caudosinistrally, then caudally following sinuous path to caudal margin of annulus (Fig. F).

Type locality: Stream tributary to Ouachita River, 6 mi. northwest of Mt. Ida, Montgomery County, Arkansas.

Disposition of the types: The holotypic male, Form I; the allotypic female; and the morphotypic male, Form II, are in the collections of the United States National Museum (nos. 115517, 115518, and 115519, respectively). Paratypes are deposited in the U. S. National Museum (nos. 114821 and 114822), the Museum of Comparative Zoology, Harvard University (no. 12637), Tulane University (parts of Lots 2500, 2956, 3081, 3082, 3083, 3150, 3346, 3364, 3443, 3444, 3450, and 3451), and in personal collections of the author. The paratypic series is a total of 218 specimens representing both forms of the male, females, and juveniles of both sexes. The specimens at MCZ and in collections of the author are among specimens designated topoparatypes.

Range: This subspecies is confined to tributaries of the Ouachita River and has been collected from the following counties in Arkansas: Garland, Hot Springs, Montgomery, Perry, Pike, Polk, and Saline.

Variations: There are relatively few variations in the specimens examined. In some there are less pronounced cephalomedian projections of the epistome, and in a few specimens the projection is lacking. In some specimens the terminal elements of the pleopod are longer than usual, resulting in a greater central projection: mesial process ratio. Lateral tubercles of the carapace are lacking in many specimens.

Relationships: Orconectes leptogonopodus **acares** has its closest affinities with *O. l. leptogonopodus* Hobbs. Although there are no evidences of intergrade populations among the specimens examined, Jones Creek and Caddo River specimens show definite tendencies toward typical *leptogonopodus* morphology, and specimens of *O. leptogonopodus leptogonopodus* from McCurtain County, Oklahoma, show definite tendencies toward morphological features of *O. leptogonopodus* **acares.** *O. l. leptogonopodus* appears to be restricted to tributaries of the

TABLE I.
Measurements of type specimens of Orconectes leptogonopodus **acares.**
(All measurements in mm)

		Holotype	Allotype	Morphotype
Carapace—	height	6.9	10.4	7.5
	width	8.7	8.7	8.7
	length	17.8	25.3	18.0
Areola—	length	6.1	8.6	5.9
	width	0.9	1.2	1.1
Rostrum—	length	4.9	5.9	5.0
	width	2.8	3.4	3.0
Chela—	length of inner margin of palm	5.0	7.0	4.8
	width of palm	6.5	8.5	6.3
	length of outer margin of palm	14.1	19.1	12.9
	length of dactyl	8.5	10.7	7.7

Red River in Arkansas and eastern Oklahoma, while *O. l.* **acares,** is confined to tributaries of the Ouachita River, from the Caddo River upstream. *O. l.* **acares** may be distingiushed from *O. l. leptogonopodus* by a shorter pleopod, a shorter central projection, and a smaller central projection: mesial process ratio (mean value for **acares:** 1.34; for *leptogonopodus:* 1.43). In *O. l.* **acares** there is a greater tendency toward development of a cephalomedian projection of the epistome, and there are slight differences between the two subspecies in outline of the cephalic margin of the annuli ventrales.

Remarks: Orconectes leptogonopodus has never been reported from outside the state of Arkansas, but two collections in the USNM are from Oklahoma: (1) 8 Oct. 1955, McCurtain Co. (?), Eagle Creek, trib. to Mountain Fork Riv., nw of Smithville, coll. A. P. Blair (?) (Hobbs Collections); and (2) 28 Nov. 1963, McCurtain Co., Broken Bow, 6 NNE, coll. A. P. Blair, and both of these contained specimens which I identified as *O. l. leptogonopodus.*

Literature Cited

Hobbs, H. H. Jr., 1948. Two new crayfishes of the genus *Orconectes* from Arkansas with a key to the species of the Hylas Group. *Amer. Midl. Nat.* 39: 139-150.

_____, 1962. Notes on the affinities of the members of the Blandingii Section of the crayfish genus *Procambarus. Tulane Stud. Zool.* 9: 273-293.

Williams, A. B. 1954. Speciation and distribution of the crayfishes of the Ozark Plateaus and Ouachita Provinces. *Univ. Kansas Sci. Bull.* 36: 803-918.

June 23, 1965

TULANE STUDIES IN ZOOLOGY

Volume 12, Number 4 October 11, 1965

ECOLOGICAL DISTRIBUTION AND ACTIVITY PERIODS OF BATS OF THE MOGOLLON MOUNTAINS AREA OF NEW MEXICO AND ADJACENT ARIZONA

CLYDE JONES

Department of Biology, Tulane University
New Orleans, Louisiana

Abstract

Data concerning ecology and distribution are presented and summarized for 19 species of bats from southwestern New Mexico and adjacent southeastern Arizona. Time of capture and air temperature at time of capture are given for all species. Environmental factors that may influence activity and distribution of bats are discussed.

Introduction

Few observations have previously been published on bats in New Mexico, and information on general ecology has often been incidental to distributional or taxonomic studies. Bailey (1931), while presenting geographic ranges of bats known from New Mexico, made some mention of ecology and natural history. More recently, limited ecological information has been contributed by Mumford (1957, 1964), Commissaris (1959), Findley (1960), Constantine (1961a, b), Harris (1963), and others. Sheppard (1962) assembled natural history and ecological data for the species of bats occurring in Bernalillo Co., New Mexico.

The purpose of this report is to furnish information concerning distribution and general ecology and to discuss briefly the factors that may influence activity and distribution of bats of the Mogollon Mountains area of southwestern New Mexico and adjacent southeastern Arizona.

Description of the Area

Fenneman (1931) included the northern part of the study area (north of 33° N lat) in the Datil section of the Colorado Plateau physiographic province and the southern part (south of 33° N lat) in the Mexican Highland division of the Basin and Range province. The study area is composed of a portion of the Mogollon Rim and several semi-isolated and isolated smaller mountain ranges bordered on the north by the closed basin of the San Augustin Plains and on the east and south by the Rio Grande and Gila River drainages (Fig. 1). From the lowest elevation of 3,800 ft on the Gila River at the Arizona-New Mexico border the altitude rises to 10,788 ft in elevation at the highest point, Mogollon Peak. Precipitation in the area is variable, ranging from about 10 to 16 inches annually (little or no weather data are available from montane areas), with the heaviest rainfall occurring in July and August (Hardy, 1941).

The Mogollon Mountains area has biotic communities characteristic of the southern Rocky Mountains (Lowe, 1964). For the purposes of this study, three biotic communities are recognized.

Xeric-shrub grassland.—Present and widespread below 6,000 ft except for restricted stands of evergreen and deciduous vegetation on north-facing slopes and canyon

Editorial Committee for this Paper:

Andrew A. Arata, Associate Professor of Zoology, Tulane University, New Orleans, Louisiana

Dr. Martin Eisentraut, Museum Alexander Koenig, Bonn, West Germany

Philip H. Krutzsch, Professor and Head of Anatomy, College of Medicine, University of Arizona, Tucson, Arizona

floors. Conspicuous species of plants found in the xeric-shrub grassland are *Muhlenbergia wrightii, Bouteloua gracilis, Atriplex canescens, Chrysothamnus* spp., *Larrea tridentata, Prosopis juliflora,* and *P. pubescens* with *Populus* spp., *Tamarix gallica,* and *Eleagnus angustifolia* commonly riparian.

Evergreen-deciduous woodland.—Present throughout the study area from below 5,000 ft on north-facing slopes to above 7,000 ft on ridges and south-facing slopes. Some plants that make up the evergreen-deciduous woodland are *Juniperus monosperma, J. scopulorum, J. deppeana, Pinus edulis, Quercus grisea, Q. gambelii,* and *Cercocarpus breviflorus.*

Evergreen forest.—Widespread above 7,000 ft, present in restricted stands at lower elevations and in heads of cool, mesic canyons. Some common species of plants of the evergreen forest are *Pinus ponderosa, P. flexilis, P. edulis, Picea engelmannii, P. pungens, Abies concolor, A. lasiocarpa, A. lasiocarpa* var. *arizonica, Pseudotsuga mensiesii, Quercus gambelii,* and *Populus tremuloides* with *Salix* spp., *Alnus tenuifolia,* and *Acer* spp. often riparian.

Methods and Materials

Bats were, for the most part, captured in mist nets stretched across water tanks, over ponds and streams, or over entrances to mines and caves. Nets were maintained ordinarily for 5 to 6 hrs per night. Attempts were often made to maintain nets all night, however, nets frequently were left standing unattended all night and were checked during the early morning hours. In addition to those netted, a few bats were shot. Most data presented here were gathered in 1960, but limited field studies were conducted from 1958 through 1963.

Whenver possible, time of capture, air temperature at the time of capture, and sex

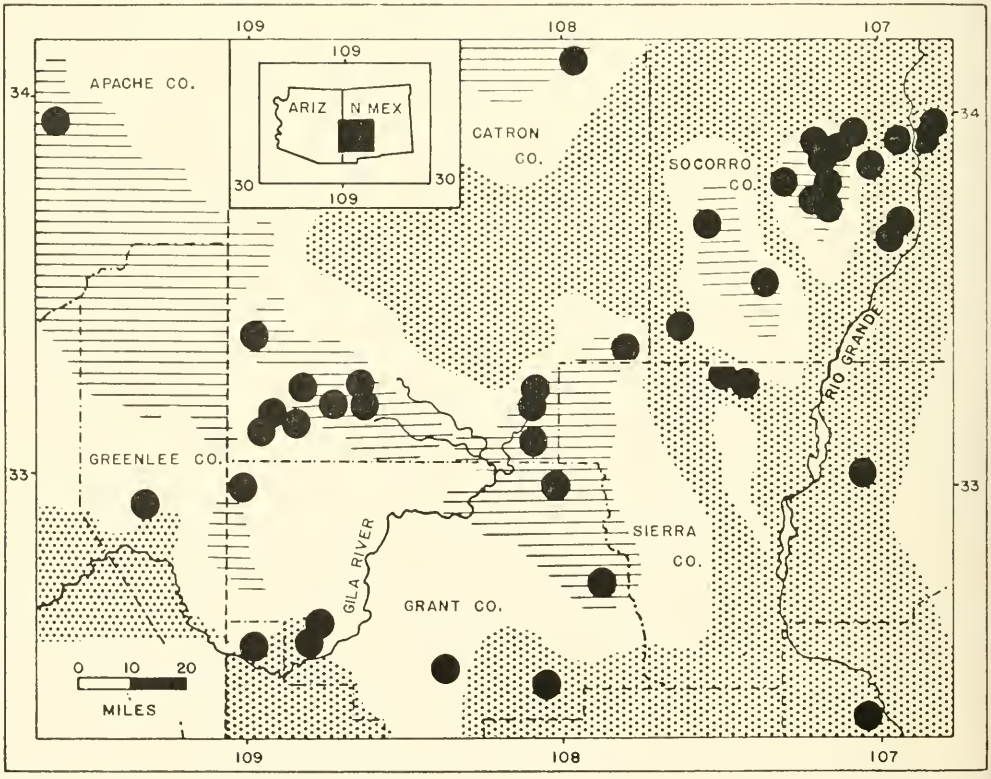


Figure 1. Map of the study area showing biotic communities and collecting stations. Evergreen forest is represented by lined areas, evergreen-deciduous woodland is represented by white areas, and xeric-shrub grassland is represented by stippled areas. The distribution of collecting stations is a reflection of the presence of permanent water over which to sample bats.

of each individual were recorded upon collection of the bat. Data on time of capture and air temperature at the time of capture were analyzed and compared by means of standard statistical methods; arithmetic mean, standard deviation, and standard error of the mean were computed. Because there were no significant differences between the two sexes in time of capture or air temperature at time of capture, data for males and females were combined. Weather conditions were noted in an attempt to determine the role of such factors as wind, rain, and moonlight in relation to activity of the animals studied.

In all, 1595 specimens were obtained from the study and were preserved in the Museum of Southwestern Biology at the University of New Mexico either as standard museum study skins and skulls with carcasses preserved in fluid or were preserved entire in fluid.

Results

The Chiropteran fauna of each of the biotic communities is summarized in Table 1. On the basis of the data presented herein, 13 species of bats are considered to be highland forms (greatest percentage of individuals collected were from localities in evergreen forest generally above 7,000 ft in elevation), and six species are regarded as lowland forms (greatest percentage of individuals collected were taken at localities in xeric-shrub grassland and evergreen-deciduous woodland mostly below 7,000 ft in elevation). *Myotis occultus* is equally

Table 1.

Percentage of each species and percentage of all bats collected in each biotic community, as well as bats collected per station (number of bats collected in a community divided by the number of collecting stations in that community) in each biotic community.

	Total number taken	Percent of total number taken in xeric-shrub grassland	Percent of total number taken in evergreen-deciduous woodland	Percent of total number taken in evergreen forest	Bats taken per station in xeric-shrub grassland	Bats taken per station in evergreen-deciduous woodland	Bats taken per station in evergreen forest
Myotis californicus	22		35.0	65.0		.77	.68
Myotis evotis	61			100.0			3.05
Myotis keenii	42		14.3	85.7		.66	1.86
Myotis occultus	66	45.5		54.5	2.0		1.80
Myotis subulatus	35	13.5	21.5	65.0	.33	.88	1.26
Myotis thysanodes	84		4.7	95.3		.44	4.31
Myotis velifer	3	33.4	66.6		.06	.22	
Myotis volans	226		2.6	97.4		.66	11.00
Myotis yumanensis	137	89.6	5.2	5.2	3.46	.33	.15
Lasionycteris noctivagans	105		25.8	74.2		3.00	4.10
Pipistrellus hesperus	43	58.1	39.5	2.4	1.66	1.42	.05
Eptesicus fuscus	277	1.5	9.0	89.5	.26	2.77	12.40
Lasiurus borealis	4		100.0			.44	
Lasiurus cinereus	191	2.2	41.3	56.5	.26	8.77	5.86
Plecotus phyllotis	31		9.7	90.3		.33	1.47
Plecotus townsendii	39	8.0	18.4	73.6	.20	.77	1.47
Euderma maculatum	7			100.0			.36
Antrozous pallidus	95	45.2	37.4	17.4	2.86	4.00	.84
Tadarida brasiliensis	126	32.8	54.4	12.8	2.73	7.55	.84
Tadarida molossa	1			100.0			.05
Total	1595	13.7	19.9	66.4	13.80	33.50	50.30

distributed in the xeric-shrub grassland and in evergreen forest, whereas *Myotis evotis* is restricted to the evergreen-forest community. *Myotis velifer, Lasiurus borealis, Euderma maculatum,* and *Tadarida molossa* were taken on too few occasions to determine the true habitats of the species. *Lasionycteris noctivagans* and *Lasiurus cinereus,* considered here as highland species, were taken at lower elevations during April, May, and June, but were more abundant at higher elevations in July and August. Vaughan and Krutzsch (1954) suggest a similar distribution for *L. cinereus* in southern California.

The seasonal distributions of each species of bats is summarized in Table 2. Four species (*Myotis velifer, Lasiurus borealis, Euderma maculatum,* and *Tadarida molossa*) perhaps are represented by insufficient numbers to give a valid indication of seasonal distributions of the species. Bats were most abundant in the study area during June and July (Table 2) and were least abundant during August. Females were more abundant than males in April and May, but males were slightly more abundant than females during the remainder of the season of study.

The range of time, expressed in minutes after sunset, in which each species was active is presented in Fig. 2. Three species (*Myotis californicus, M. occultus,* and *Pipistrellus hesperus*) were active mostly during the first 1 hr and 40 min after sundown. Mumford (1964) and Cockrum and Cross (1964) present similar data for *P. hesperus.* Other species (*Myotis evotis, M. subulatus, M. velifer, M. yumanensis, Lasiurus cinereus, Plecotus townsendii, Euderma maculatum, Antrozous pallidus,* and *Tadarida brasiliensis*) seemingly have a later period of activity, mostly after the first 1 hr and 40 min after sundown. The seven remaining species seem to be active during a period intermediate to the two aforementioned groups. The data indicate peaks in the activity of the animals during the first 2 hrs after sunset (Fig. 2). In only one case was predawn collecting successful.

Air temperature at capture is given for each species in Fig. 3. For those species where ten or more individuals are represented, a few general trends are suggested: *Plecotus phyllotis* was taken in a narrow range of temperature from 9 to 17° C, whereas *Lasionycteris noctivagans* (minus 2 to 20° C), *Lasiurus cinereus* (0 to 22° C), and *Tadarida brasiliensis* (7 to 27 °C) were active through a wide range. A high temperature preference, mostly above 20° C, was shown by *Myotis velifer, Lasiurus bore-*

TABLE 2.

Numbers of bats of each species taken per night each month (number of bats collected each month divided by the number of nights bats were collected in each month). The total number of times bats were collected each month is given in parentheses with the name of each month.

	Total taken	April (9)	May (7)	June (36)	July (27)	Aug. (12)	Sept. (9)	Oct. (1)
Myotis velifer	3			.08				
Tadarida molossa	1				.03			
Lasiurus borealis	4		.14	.08				
Myotis occultus	66			1.08	.85	.33		
Plecotus phyllotis	31	.22		.36	.59			
Myotis californicus	22		.29	.36	.18		.22	
Myotis subulatus	35	.66		.44	.37	.25		
Myotis evotis	61		.14	.36	1.18	.41	1.11	
Myotis keenii	42	.44		.50	.28	.75	.44	
Pipistrellus hesperus	43	.22	.57	.69	.29	.33		
Antrozous pallidus	95	1.22	.29	2.09	.22		.11	
Myotis thysanodes	84	1.33	.14	1.16	.77	.16	.66	
Myotis volans	226	.77	.14	2.47	3.25	1.08	3.11	
Myotis yumanensis	137	.44	.14	.33	.77	.16	10.77	
Plecotus townsendii	39	.11	.29	.33	.11	.41	1.77	
Tadarida brasiliensis	126	.33	.29	1.55	.96	1.25	2.66	
Lasiurus cinereus	191	.44	7.85	3.02	.70		.22	1.00
Lasionycteris noctivagans	105	1.00	1.42	2.03	.29	.08	.33	1.00
Eptesicus fuscus	277	.44	.71	4.30	2.03	.91	4.77	4.00
Total	1595	7.66	12.57	21.47	12.92	6.16	26.22	6.00

alis, and *Euderma maculatum;* however, these data represent less than ten observations each, and thus may not be meaningful.

Discussion

The data presented in Table 1 provide an indication of the habitat of the various species of bats found within the study area. Inasmuch as the number of times collections were made within each plant community and the number of localities from which collections were made varied, bats collected per station may be the least biased means of comparing habitats.

The great abundance of bats in the early part of the collecting season is due to the presence of relatively large numbers of fe-

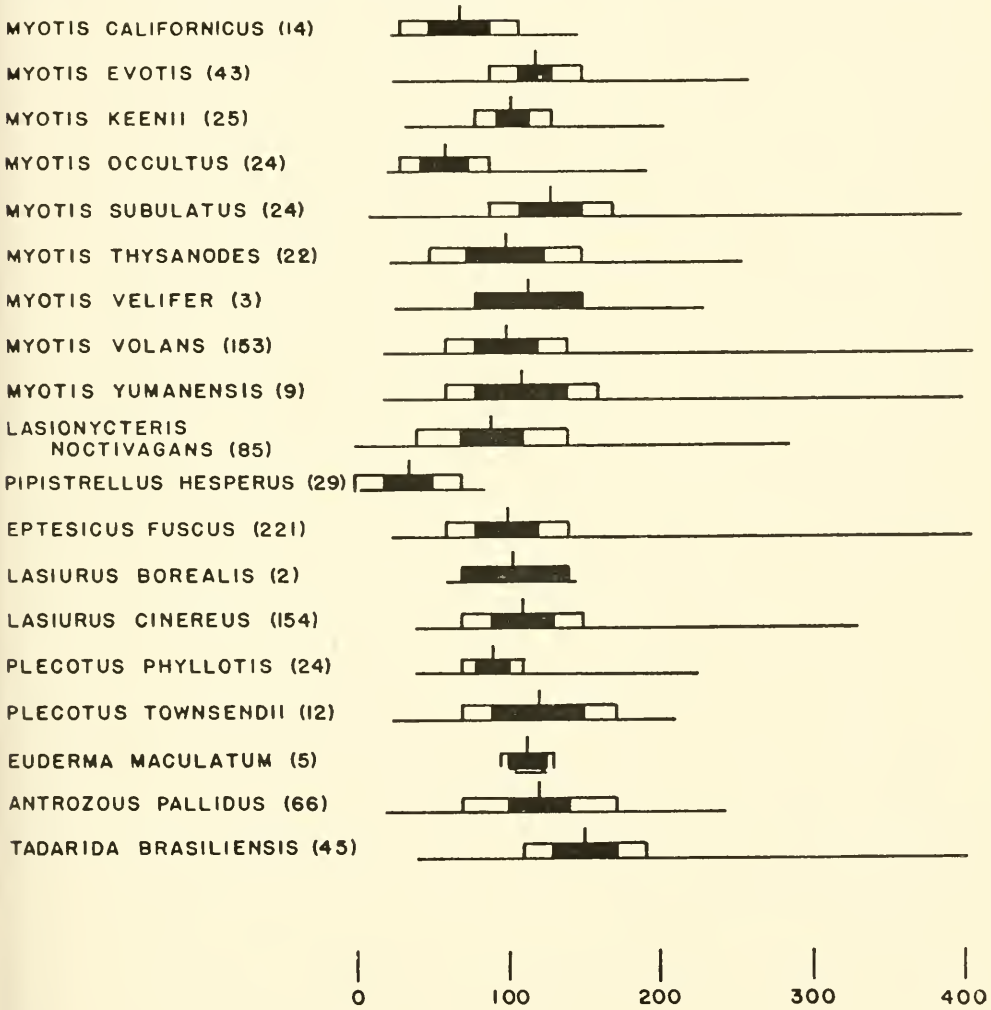


Figure 2. Range of time, expressed in minutes after sunset, in which each of 19 species of bats was active. The horizontal line represents the range, the central vertical line indicates the arithmetic mean, the shaded area represents plus or minus two standard errors of the mean, and the unshaded area encloses plus or minus one standard deviation. For each species, the total number of bats for which data are available is given in parentheses. Time of sunset was corrected for latitude after being taken from tables furnished by the United States Weather Bureau.

males, whereas the numbers of bats present later in the season may be the result of premigratory or prehibernatory groupings of some species (Table 2). The abundance of certain species (*Lasionycteris noctivagans* and *Lasiurus cinereus*) early and again late in the collecting season is a reflection of migratory movements of these animals through the study area (Findley and Jones, 1964). The small numbers of bats taken in the study area during August may have been caused by heavy rains during late July and August and resultant abundance of watering places. Observations during the rainy period indicated some decrease in numbers of bats in areas where heavy concen-

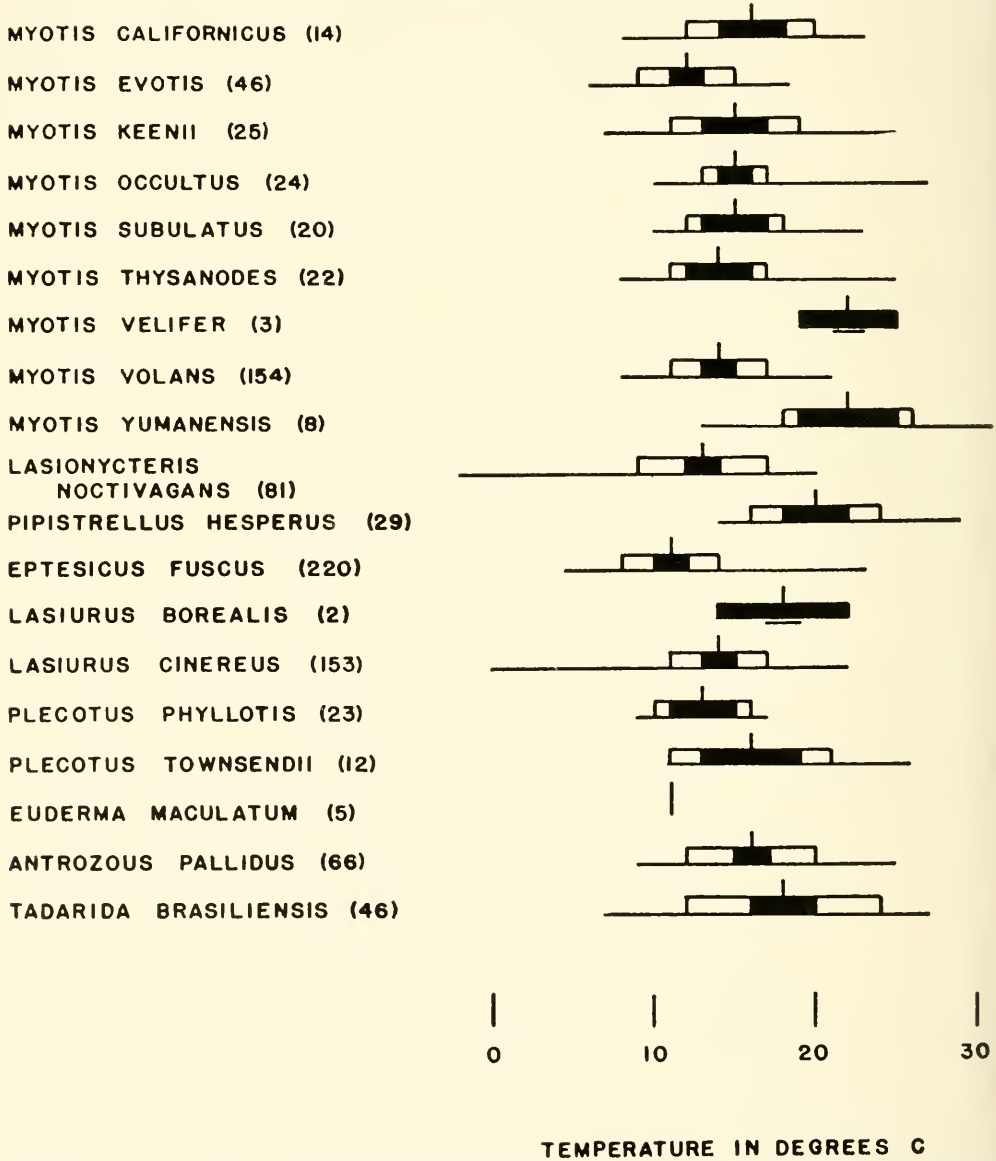


Figure 3. Range of air temperature in which each of 19 species of bats was active. The horizontal line represents the range, the central vertical line indicates the arithmetic mean, the shaded area represents plus or minus two standard errors of the mean, and the unshaded area encloses plus or minus one standard deviation. For each species, the total number of bats for which data are available is given in parentheses.

trations were previously noted. Because of the increased availability of drinking water, bats probably were more widely dispersed during late July and August. Although water-hole samples of bats are considered herein as indicators of the entire community, it is realized that there is differential probability in the capture of bats in mist nets (Cockrum and Cross, 1964).

Bats are well known for marked periodicites in their normal habits (Griffin and Welsh, 1937). During the summer, bats of the species considered here probably spend the day in roosts and emerge after sundown to seek food and water. Depending perhaps on the abundance of food and on temperature, bats may return to the roosts after a time or may forage throughout the night. Gould (1961) reported that light intensity and rain are important factors that influenced the time of emergence of *Tadarida femorosacca,* and suggested that temperature and total solar radiation during the day did not affect the time of emergence. Baker (1961) noted a general trend in the emergence of *Tadarida brasiliensis* from late times of flight in May to early times of flight in October. Analysis of the data presented in Figs. 2 and 3 indicated that there is some correlation between air temperature and time capture of some species of bats. Members of one species, *Myotis evotis,* were active during a low range of temperature and were captured at time somewhat later than other related species, but for another species, *Pipistrellus hesperus,* the converse was true. Some bats (*Myotis yumanensis* and *Pipistrellus hesperus*) that were active during warm temperatures were taken either for a short period of time early in the evening or were active for longer periods of time only when warm temperatures prevailed. Drinking and feeding activity of bats apparently is correlated with the air temperature. Any relationship of temperature to the time of emergence of the species considered here is obscured by the nature of the data. The observations reported here do not permit speculation as to the distance bats may travel from roosts to watering areas and no evidence is available as to how soon after leaving the diurnal roosts bats approach water surfaces. Some bats may fly directly from roosts to water (Hayward and Davis, 1964), but other bats may follow an indirect route to water.

In general, the ranges of temperatures in which the species of bats were active coincide with distribution and habitat of the animals. The species *(Plecotus phyllotis)* that was active in a narrow range of temperature (9 to 17° C) is more limited in geographic distribution than those species (*Lasionycteris noctivagans* and *Lasiurus cinereus*) that were active through a wide range of temperature (minus 2 to 20° C and 0 to 22° C). *Myotis evotis,* for which a low temperature preference was indicated (6 to 18° C), was not taken at low elevations (below 7,000 ft) and *Myotis velifer, M. yumanensis,* and *Pipistrellus hesperus,* for which high temperature preferences were indicated (21 to 23° C, 19 to 31° C, and 14 to 29° C), were rarely taken at high elevations (above 7,000 ft). Preference for high temperatures suggest that some of the so-called lowland species of bats (*Myotis velifer, M. yumanensis,* and *Pipistrellus hesperus*) possibly are incapable of inhabiting highland areas, at least within the latitudes encompassed in this study. The converse may be true for the so-called highland form *(Myotis evotis).* On the other hand, the data indicate that some species (*Lasionycteris noctivagans* and *Lasiurus cinereus*), for which low temperature preferences are suggested, inhabit regions of high or low elevation and north or south latitudes concordant with season.

Activity of the bats included here, seemingly, was not affected by weather conditions, although Sheppard (1962) and Gould (1961) suggest that factors such as wind, humidity, cloud cover, and moonlight may influence the activity of bats. Wind and moisture seemed to influence only the number of bats caught, not the number observed. On many occasions bats were seen drinking, flying about, and striking a net blown so tightly by the wind that no animals became entangled in the mesh. Several times bats were captured when foggy conditions prevailed and on a few occasions were taken during heavy showers.

Distribution of certain tree-roosting bat species is influenced by vegetation. For the other species of bats reported herein, few data are available to indicate any direct correlation between bat distribution and specific vegetation. Distribution of bats perhaps is influenced by the availability of suitable roosting sites, proper amounts of food

materials, and adequate water surfaces for drinking. Temperatures must be considered an important factor influencing certain activities and, perhaps, the distribution of bats.

Summary

Of the 19 species of bats occurring in the study area, 13 species were collected in highland areas (above 7,000 ft), six species were taken in lowland regions (below 7,000 ft), and one species was distributed equally in lowland and in highland areas. Only one species was restricted in distribution to a particular community.

Bats were most abundant in the study area during June and July. Females outnumbered males in the spring, but males were slightly more abundant than females during the summer and early fall.

Three species of bats were active during the first 1 hr and 40 min after sundown, nine species were active during a later period of time, and seven species were active during a period intermediate to the aforementioned groups.

Some species were taken in a narrow range of temperature (8° C); other species were taken in a wide range (20° C). Preferences for high temperatures were indicated by three species and preferences for low temperatures were detected for several species. The ranges of temperatures in which bats were active correlate with distribution and habitat of the animals.

Acknowledgments

James S. Findley, Eugene Fleharty, David Niles, John Wright, Eugene Schroeder, Arthur Harris, and Dick Forbes either helped in the field or contributed specimens from the study area. I received financial assistance from the National Science Foundation during 2 months in each of the summers of 1958 and 1959, and for 3 months during the summer of 1960.

Literature Cited

Bailey, V. 1931. Mammals of New Mexico. *N. Am. Fauna* 53:1-412.

Baker, J. 1961. What about bats? *Carlsbad Caverns Nat. Hist. Assoc.* 55 p.

Cockrum, E. L., and S. Cross. 1964. Time of bat activity over water holes. *J. Mammal.* 45:635-636.

Commissaris, L. 1959. Notes on the Yuma *Myotis* in New Mexico. *J. Mammal.* 40: 441-442.

Constantine, D. 1961a. Locality records and notes on western bats. *J. Mammal.* 42:404-405.

Constantine, D. 1961b. Spotted bat and big free-tailed bat in northern New Mexico. *Southwestern Nat.* 6:92-97.

Fenneman, N. 1931. *Physiography of western United States.* McGraw-Hill Book Company, Inc., New York. 714 p.

Findley, J. 1960. Identity of the long-eared Myotis of the Southwest and Mexico. *J. Mammal.* 41:16-19.

Findley, J., and C. Jones. 1964. Seasonal distribution of the hoary bat. *J. Mammal* 45:461-470.

Gould, P. 1961. Emergence time of *Tadarida* in relation to light intensity. *J. Mammal.* 42:405-407.

Griffin, D., and J. Welsh. 1937. Activity rhythms in bats under constant external conditions. *J. Mammal.* 18:337-342.

Hardy, E. 1941. *Climate of New Mexico. In* Climate and Man, Yearbook of Agriculture: 1011-1024. U. S. Dept. of Agriculture, Washington, D. C.

Harris, A. 1963. Ecological distribution of some vertebrates in the San Juan Basin, New Mexico. *Museum of New Mexico Press, Papers in Anthropol.* 8:1-63.

Hayward, B., and R. Davis. 1964. Flight speeds in western bats. *J. Mammal.* 45: 236-242.

Lowe, C. 1964. *Arizona landscapes and habitats. In* Vertebrates of Arizona. Univ. Arizona Press, Tucson. 132 p.

Mumford, R. 1957. *Myotis occultus* and *Myotis yumanensis* breeding in New Mexico. *J. Mammal.* 38:260.

Mumford, R. 1964. June bat records from Guadalupe Canyon, New Mexico. *Southwestern Nat.* 9:43-45.

Sheppard, F. 1962. An annotated checklist of the bats of Bernalillo County, New Mexico. *M. S. Thesis. Univ. New Mexico.* 101 p.

Vaughan, T., and P. Krutzsch. 1954. Seasonal distribution of the hoary bat in southern California. *J. Mammal.* 35:431-432.

ETHEOSTOMA (OLIGOCEPHALUS) NUCHALE, A NEW DARTER FROM A LIMESTONE SPRING IN ALABAMA

WILLIAM MIKE HOWELL
and
RICHARD DALE CALDWELL
Department of Biology, University of Alabama
University, Alabama

ABSTRACT

Etheostoma (Oligocephalus) nuchale is described from 71 specimens collected from a limestone spring in the Black Warrior River system near Bessemer, Jefferson County, Alabama. *E. nuchale* is known only from Glen Spring, the type locality, which is located above the Fall Line. It is compared to its nearest known relative, *E. swaini* (Jordan), from which it is geographically isolated. *E. swaini* does not normally cross the Fall Line, and is a wide-ranging species found along the Gulf Coastal Plain from the Ochlockonee River in Florida to the Amite River system of southeastern Louisiana and southern Mississippi. The species differ in details of body proportions, squamation, pigmentation, development of lateral line and cephalic sensory canals, certain fin-ray counts and habits.

On 21 March 1964, Dr. Ronald A. Brandon and Ron Altig collected three specimens of an undescribed darter while dip-netting for salamanders in Glen Spring at Bessemer, Jefferson County, Alabama. On 24 March 1964, we visited the spring and obtained 51 additional specimens. This distinctive species differs consistently from its nearest known relative, *Etheostoma swaini* (Jordan), in details of body proportions, squamation, pigmentation, development of lateral line and cephalic sensory canals, certain fin-ray counts, and habits.

Counts and measurements were obtained by methods defined by Hubbs and Lagler (1958: 19-26) unless otherwise noted. Techniques of Hubbs and Cannon (1935) were used in making measurements to the nearest 0.1 mm. Proportional measurements are expressed as thousandths of the standard length.

We wish to thank the following individuals who have aided us in this study: Dr. Ronald A. Brandon and Ron Altig of the University of Southern Illinois first collected specimens of this handsome new species and made them available to us; Dr. Herbert T. Boschung, Jr., our major professor, continually encouraged us and gave many helpful suggestions; Dr. Ralph Chermock of the University of Alabama criticized our manuscript in its early stages; Dr. Ralph Yerger of Florida State University permitted us to examine his unpublished data on *Etheostoma swaini* and also made radiographs for us; Dr. Royal D. Suttkus and John S. Ramsey of Tulane University made available to us a collection of the species described herein; Dr. Reeve M. Bailey of the University of Michigan criticized the final draft of our manuscript and made many helpful suggestions.

Etheostoma **nuchale**, sp. n.
Watercress Darter
(Fig. 1)

Material.—The holotype, University of Michigan Museum of Zoology, UMMZ 187523, an adult male, 39.4 mm in standard length, was collected by us on 24 March 1964 in Glen Spring at Bessemer, Jefferson County, Alabama (NE¼ SE¼ Sec 17, T 19S, R 4W) along county highway 20. In

EDITORIAL COMMITTEE FOR THIS PAPER:

REEVE M. BAILEY, Curator of Fishes, Museum of Zoology, University of Michigan, Ann Arbor, Michigan

ROYAL D. SUTTKUS, Professor of Zoology, Tulane University, New Orleans, Louisiana

RALPH W. YERGER, Professor of Zoology, Department of Biological Sciences, Florida State University, Tallahassee, Florida

the same collection we obtained the following specimens: the allotype, UMMZ 187524, an adult female 39.8 mm in standard length; 20 paratopotypes, UMMZ 187525; 20 paratopotypes, U. S. National Museum, USNM 259800-F1; and 9 paratopotypes, University of Alabama Ichthyological Collection, UAIC 1227. Twenty paratopotypes, Tulane University No. 34591, were collected on 9 September 1964 by Dr. Royal D. Suttkus, John S. Ramsey, and Francis L. Rose.

At present this species is known only from the type locality in the Black Warrior River system of Alabama.

Diagnosis.—A species of *Etheostoma* of the subgenus *Oligocephalus* (Bailey and Richards, 1963) distinguished by: lateral line incomplete, moderately straight; supratemporal canal incomplete; infraorbital canal usually incomplete; nape naked mesially; top of head, breast, and prepectoral areas naked; cheek largely naked but always with few to several embedded or exposed scales along posteroventral margin of eye; opercle with large exposed or embedded, ctenoid scales; body scales large, with 35-42 scales in the lateral series; 12-24 pored scales in lateral line; branchiostegal membranes moderately to narrowly conjoined, sometimes overlapping anteriorly. Fin-rays: dorsal VIII to XI (usually IX or X), 10 to 12; anal II (rarely III), 6 to 8; pectoral 11 or 12. Nape distinctly humped, usually decurving sharply to occiput. Breeding adults with a submarginal red band in spinous dorsal fin.

Description.—A moderately robust species with body slightly compressed; snout moderately pointed to somewhat rounded; pectoral fin shorter than head length; 11 to 14 branched caudal rays; 15 to 17 scale rows around caudal peduncle, of which 6 to 8 (usually 7) are above the lateral series and 6 to 8 (usually 7) are below; transverse scales are 10 to 12 (counted from origin of second dorsal fin posteroventrally to anal fin base); supratemporal canal incomplete,

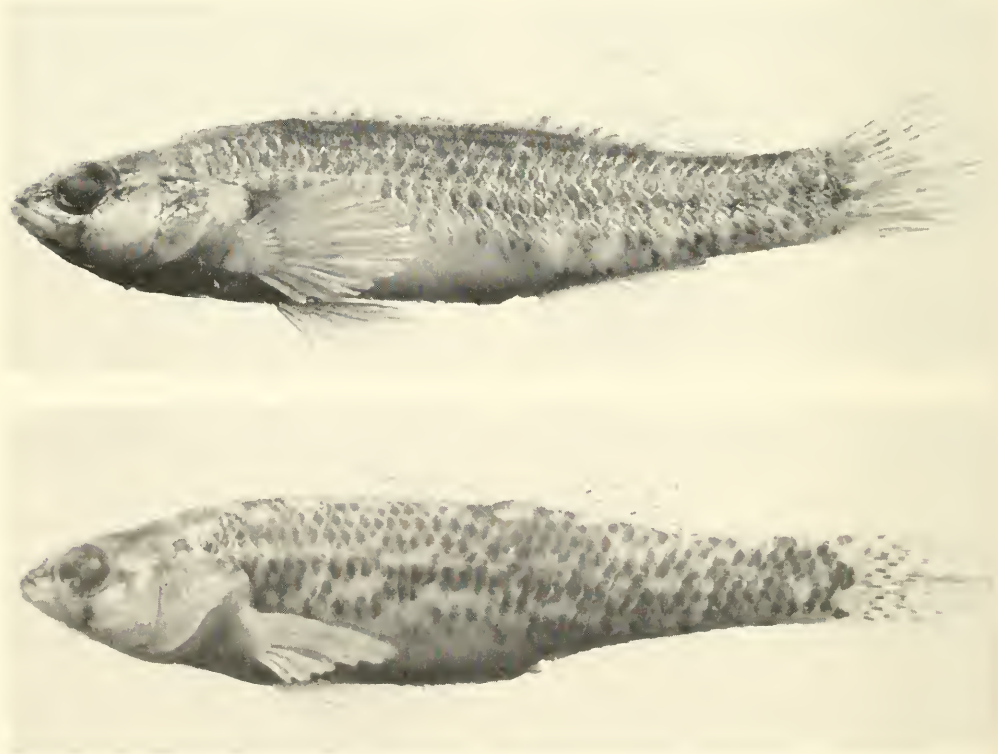


Figure 1. Top. *Etheostoma* **nuchale**, sp. n. Adult male holotype, 39.4 mm in standard length (UMMZ 187523).
Bottom. *Etheostoma* **nuchale**. Female allotype, 39.8 mm in standard length (UMMZ 187524).

TABLE 1.

Comparison of Proportional Measurements of Etheostoma **nuchale** *and E. swaini*[1] *(Expressed As Thousandths of Standard Length)*

Species	*Etheostoma nuchale*				*Etheostoma swaini*	
Museum number	UMMZ 187523 Holotype	UMMZ 187524 Allotype	UMMZ 187525 Paratypes	UMMZ 187525 Paratypes	UAIC 929, 1112, 1113, 1150, 1162 and 1184	UAIC 1060, 1090, 1162, 1180 and 1192
Sex	M	F	M	F	M	F
Number of specimens	1	1	10	10	10	10
Standard length, mm	39.4	39.8	34.9 (30.6-38.3)	36.6 (27.1-45.2)	35.9 (25.9-43.7)	37.3 (28.9-44.7)
Head length	281	282	280 (264-293)	274 (257-288)	294 (272-306)	295 (270-313)
Head width	167	164	176 (164-188)	171 (162-181)	162 (148-176)	163 (148-178)
Snout length	53	48	52 (45-61)	51 (45-57)	53 (43-60)	55 (46-59)
Orbit length	76	78	78 (72-86)	77 (67-88)	85 (75-93)	87 (79-96)
Fleshy interorbital width	61	50	59 (54-62)	54 (45-60)	55 (50-63)	57 (52-64)
Upper jaw length	79	78	73 (60-82)	72 (65-78)	83 (76-92)	81 (74-97)
Lower jaw to juncture of gill membranes	134	118	128 (110-152)	122 (102-140)	124 (115-133)	123 (114-135)
Head depth at occiput	188	196	199 (193-216)	194 (180-206)	186 (172-200)	190 (177-202)
Body depth at dorsal origin	226	241	228 (212-238)	228 (216-244)	211 (196-231)	210 (190-242)
Body width	150	153	148 (131-161)	148 (132-162)	142 (134-151)	152 (135-172)
Longest pectoral ray	239	234	243 (231-255)	239 (221-252)	274 (249-301)	268 (223-284)
Pelvic fin length	206	204	220 (193-234)	210 (187-237)	224 (191-239)	214 (191-224)
Pelvic fin base	38	38	37 (33-40)	35 (33-37)	40 (36-44)	35 (31-39)
Transpelvic distance	79	70	74 (69-78)	69 (66-72)	83 (80-86)	79 (76-87)
Interpelvic space	15	18	16 (13-20)	16 (13-20)	20 (14-23)	19 (16-22)
Pelvic insertion to juncture of gill membranes	180	191	186 (177-195)	180 (172-195)	190 (175-204)	199 (170-218)
Highest dorsal spine	117	123	125 (113-141)	109 (97-124)	138 (128-154)	125 (104-133)
Highest dorsal soft ray	165	153	167 (153-179)	156 (137-168)	167 (151-180)	158 (142-166)
First anal spine	79	78	85 (76-96)	74 (67-97)	85 (74-96)	80 (69-93)
Highest anal soft ray	152	156	166 (154-177)	155 (140-171)	153 (137-166)	137 (127-150)
Caudal peduncle length	223	262	247 (235-263)	248 (227-262)	260 (234-282)	259 (242-267)
Caudal peduncle depth	127	118	123 (118-130)	117 (102-130)	118 (106-128)	115 (108-129)
Caudal fin length	195	211	216 (190-248)	221 (191-246)	230 (210-262)	227 (202-246)

[1] All specimens of *E. swaini* from the Black Warrior River system

TABLE 2.
Frequency Distribution of Fin-Ray Counts in Etheostoma **nuchale** *and E. swaini*[1]

Species	Dorsal Spines							Soft Dorsal Rays					
	VIII	IX	X	XI	XII	N	Mean	10	11	12	13	N	Mean
E. nuchale	7	**32**	11	1		51	9.12	8	**30**	13		51	11.10
E. swaini			17	32	2	51	10.70		19	31	1	51	11.65

Species	Anal Spines			Anal Soft Rays				
	II	III*	N	6	7	8	N	Mean
E. nuchale	**50**	1	51	3	**41**	7	51	7.08
E. swaini	51		51	13	35	3	51	6.80

Species	Total Pectoral Rays (both sides)										Branched Caudal Rays							
	22	23	24	25	26	27	28	29	N	Mean	11	12	13	14	15	16	N	Mean
E. nuchale	**16**	4	31						51	23.29	1	**7**	14	22			44	13.30
E. swaini			7	5	33	2	3	1	51	25.61		3	12	24	5	1	45	13.76

[1] All *E. swaini* from Black Warrior River system
* Atypical fin has count of III, 7

TABLE 3.
Frequency Distribution of Scale Row Counts in Etheostoma **nuchale** *and E. swaini*[1]

Species	Scales In Lateral Series																
	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	N	Mean
E. nuchale						4	**12**	8	11	10	4	1	1			51	37.62
E. swaini						1	–	6	9	8	8	8	3	5	3	51	39.84

	Scales In Transverse Series																
			10		11		12		13							N	Mean
E. nuchale			23		**23**		5									51	10.65
E. swaini			2		35		13		1							51	11.25

	Scales Around Caudal Peduncle																
			15		16		17		18		19					N	Mean
E. nuchale			9		**40**		2									51	15.86
E. swaini					9		28		10		4					51	17.18

[1] All *E. swaini* from Black Warrior River system

TABLE 4. (Continued on opposite page)
Development of Lateral Line in Etheostoma **nuchale** *and E. swaini*[1]

Species	Pored Scales In Lateral Line														
	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
E. nuchale	3	3	4	5	7	4	7	**8**	1	7	–	1	1		
E. swaini															

Species	Unpored Scales In Lateral Series													
	3	4	5	6	7	8	9	10	11	12	13	14	15	16
E. nuchale													4	1
E. swaini	1	5	4	10	12	7	5	5	2					

[1] All *E. swaini* from Black Warrior River system

with 2 pores on each side branch; lateral canal complete with 5 (rarely 4 or 6) pores; postorbital, coronal, interorbital, posterior nasal, and anterior nasal pores present; preoperculomandibular canal complete with 10 pores; anterior portion of infraorbital canal separated from posterior portion in 85 per cent of specimens; infraorbital pores usually 3 + 5 (posterior plus anterior pores) but varies from 1 + 5 to 4 + 6 with several intermediate combinations. In two of 51 specimens the infraorbital canal is interrupted twice with pore counts of 3 + 1 + 4 and 2+ 1 + 3; one specimen has the canal interrupted three times with pore counts of 1 + 2 + 2 + 3; infraorbital canal complete with 8 pores in 15 per cent of specimens. The upper lip is bound to the snout by a well developed frenum; branchiostegal rays 6; vertebrae 34 or 35 (mean = 34.4) in counts made from radiographs of 15 specimens; holotype with 34 vertebrae; nuptial tubercles absent; genital papilla of breeding females is a short, blunt, somewhat conical tube; pored portions of lateral line conspicuous, being nearly devoid of pigment; humeral region beneath the semitransparent opercular membrane is darkened; sexual dimorphism is pronounced; general body outlines are shown in Fig. 1. Body proportions are given in Table 1. In Tables 2-4, counts for the holotype appear in boldface.

Coloration.—Sexual dichromatism is pronounced. Breeding males are brilliantly colored, breeding females are plain. The following description is of the holotype, a breeding male. Notes were made immediately after preservation. Five dark orbital bars are present on the head. A black bar which originates behind and just below the center of the eye extends backward and slightly upward almost to the origin of the lateral line. This postorbital bar is broken immediately anterior to the upper portion of the preopercular margin. A preorbital dark bar which originates in line with the center of the eye extends abruptly downward and forward, passing just below the anterior naris; it then continues along the outer edge of the premaxillary frenum and ends on the upper border of the premaxilla. The lower lip is densely punctated with melanophores near its midline. A dark suborbital bar subequal in width to the pupil extends downward and slightly forward and ends on the interopercular margin. In the interorbital area is a very short supraorbital bar which begins on the iris slightly posterior to the mid-dorsal edge of the orbit and extends about one-third the distance to the mid-dorsum. Halfway between the supraorbital and postorbital bars is a dark bar which extends obliquely backward to the supratemporal canal at a 45 degree angle to the postorbital bar. The cheek and breast are light gray with distinct, evenly scattered, stellate melanophores. The isthmus and branchiostegal membranes are darker than the breast. There is no prepectoral spot; the melanophores at the pectoral fin base are widely and evenly distributed. The humeral region beneath the semitransparent opercular membrane is dark. The lateral line is without dark pigment, and forms a conspicuous light line. The pupil is blue-gray. The iris is metallic gold. Each body scale is margined with melanophores. A large dark spot is present in the center of most body scales giving an appearance of horizontal lines along the body (Fig. 1). The genital papilla and the region immediately surrounding the anus is white. The

TABLE 4. (Continued)
Development of Lateral Line in Etheostoma **nuchale** *and E. swaini*[1]

Pored Scales In Lateral Line														
26	27	28	29	30	31	32	33	34	35	36	37	38	N	Mean
													51	17.21
		2	2	5	10	7	5	8	5	5	1	1	51	32.65

Unpored Scales In Lateral Series													
17	18	19	20	21	22	23	24	25	26	27	N	Mean
4	6	3	7	10	3	5	2	4	1	1	51	20.41
											51	7.06

[1] All *E. swaini* from Black Warrior River system

belly is bright red-orange ventrolaterally. On the mid-venter the red-orange is broken by a narrow light stripe which extends from the anal area to the interpelvic region. The bright red-orange of the belly fades abruptly into light yellowish-white at the fourth scale row below the lateral line. There are six, poorly defined vertical bars best developed on their lower halves on the posterior half of the body. The bars are two to three scale rows wide, bluish-brown in color, and are separated by poorly defined orange bars. Ventrally the red-orange of the belly extends posteriorly uninterrupted to the middle of the anal fin base where it is broken by the first complete vertical bar. The nape has an irregular-edged, light yellow stripe which extends uninterrupted along the mid-dorsum from the base of the first dorsal spine to the occiput. There are seven highly irregular dorsal saddles which are two to four times wider than the interspaces. There are three indistinct, black spots in a vertical series at the caudal fin base. Immediately behind the basicaudal spots are two large, round orange spots, one above the other. The orange spots extend a short distance onto the caudal fin. Except for the orange spots, the basal third of the caudal fin is blue; remainder of fin is clear. Melanophores on the caudal fin are confined chiefly to the rays while chromatophores are on rays and membranes. The anal fin is bright blue. The pelvic fins are blue basally becoming lighter toward the tips. The pectoral fins are largely clear, becoming light blue basally. Pectoral rays are evenly outlined with melanophores. Listed in sequence from fin margin to fin base, the first dorsal fin has the following color bands: (1) a marginal blue band, (2) a submarginal red-orange band, (3) another blue band, and (4) a basal red band. Listed in like order, the second dorsal fin has the following color bands: (1) a wide marginal blue band, (2) a submarginal light orange band, (3) an intense red band, (4) a blue band, and (5) a basal red band.

In breeding male paratypes the coloration of the cheeks, breast, and prepectoral region varies from immaculate white to dark gray. The belly is light orange, red-orange, or bright red. Prepectoral spots are present or absent. Larger specimens usually have the nape mottled while most smaller specimens possess a conspicuous light stripe extending along the mid-dorsum from the base of the first dorsal spine to the occiput. A few specimens have a vertical red bar near the middle of the caudal fin. Patches of red pigment are sometimes present on the anal fin. Dorsal saddles are highly irregular, varying in number from 4 to 9.

Females, in contrast to the brilliant nuptial colors of males, are plain. Dominant colors in females are brown and black which contrast sharply with the white of the belly, breast, cheeks, and other light areas. Melanophores are concentrated in the center of many body scales but do not produce horizontal lines as in males. The dorsum and sides of most females have interspersed black, brown and white spots which form no definite pattern (Fig. 1). Head coloration is similar to that of males. Five orbital bars are present. The nape is irregularly mottled in some specimens while most possess a prominent predorsal light stripe. The prepectoral spot is present or absent. Dorsal saddles are usually highly irregular, varying in number from 3 to 9. The median fins have rows of discrete black spots on the rays. The black spots are boldly contrasted against the clear interradial membranes. The pectoral fin rays are usually margined with melanophores while the interradial membranes are clear. The pelvic fins have melanophores on rays and membranes. The spinous dorsal is the only fin with bright color in breeding females, being similar to males but much subdued.

Habitat and habits.—The type locality, Glen Spring, is a limestone spring which issues from the base of Glen Hill and forms a small, clear creek 2-9 feet wide and 2-18 inches deep. The creek flows into a man-made lake approximately 200 yards north of the spring basin. The estimated discharge of the spring at the date of collection was 500 gallons per minute. This flow is partially dependent upon recharge from local precipitation. The flow was greatly reduced during a long dry period in November 1964 but was restored December 1964, after the drought ended. The temperature of the spring varies narrowly between 16 and 18 degrees Centigrade. The elevation at the spring is 480-500 feet above sea level. Glen Spring is located within the small portion of the Valley and Ridge Physiographic Province which extends into the eastern part of the Black Warrior River Basin.

The outflow creek is choked with dense growths of watercress, *Nasturtium officinale*. The stream bottom consists of angular gravel in riffle areas and silt and mud in areas of reduced flow and heavy watercress growth. *Etheostoma nuchale* is very habitat specific; it is found only among the watercress. We have observed *nuchale* as it perched upon the leaves and roots of watercress at mid-water depths. There it feeds upon the abundant snails, crustaceans, and insect larvae which inhabit the spring and outflow creek. In aquaria, *nuchale* moves about freely, perching here and there upon roots and leaves of aquatic plants. It does not normally inhabit the bottom as do most darters. *E. nuchale* can be collected almost anywhere along the stream course above the lake. It is absent below the lake where the stream becomes heavily polluted. The stream below the lake runs into Halls Creek which flows through a residential section of Bessemer, Alabama.

We have collected in other springs in the Birmingham-Bessemer area but have not taken *nuchale*. Most of the springs have either been exploited for public or industrial water supplies or have otherwise been altered. Glen Spring is located approximately twenty yards off the present Jefferson County Hwy. 20. The outflow creek closely parallels the highway. *E. nuchale* is in danger of extinction on the basis of its limited habitat alone. At present we are contemplating the transplantation of *nuchale* to other suitable springs in the area.

E. nuchale is abundant and very successful in the spring basin and outflow creek. Associates of *nuchale* are, in order of decreasing abundance, *Semotilus atromaculatus* (Mitchill), *Lepomis cyanellus* Rafinesque, *Etheostoma whipplei artesiae* (Hay), and *Campostoma anomalum* (Rafinesque).

Relationship.—*Etheostoma nuchale* is apparently a highly specialized derivative of *E. swaini* (Jordan), from which it is geographically isolated. *E. nuchale* is known only from the type locality which is above the Fall Line in the Black Warrior River system of Alabama. *E. swaini* normally does not cross the Fall Line and is a wide-ranging species found along the Gulf Coastal Plain from the Ochlockonee River in Florida to the Amite River system of Southeastern Louisiana and southern Mississippi (R. W. Yerger, personal communication). We have made no attempt to study variation of *E. swaini* throughout its range as this problem is currently being investigated by Dr. Ralph W. Yerger of Florida State University. Since *E. nuchale* is such a distinctive species, it has been compared only with specimens of *swaini* from the Black Warrior River system (Tables 1-5). All specimens of *swaini* are deposited in the University of Alabama Ichthyological Collection and have the following accession numbers: UAIC 677, 679, 929, 1060, 1112, 1113, 1150, 1161, 1162, 1180, 1192, 1225, 1582, all from Tuscaloosa Co., Ala.; UAIC 1184 and 1190 from Fayette Co., Ala.

Breeding males of *nuchale* and *swaini* have the same basic color pattern with the colors being more intense in *nuchale*. Females of *nuchale* and *swaini* differ markedly in color pattern: in *swaini* there are dark spots in the center of most body scales which usually produce definite horizontal lines along the body (Fig. 2); in *nuchale* there are many darkened scales but horizontal lines are not usually developed (Fig. 1). Other color differences are also apparent.

Seventy-three per cent of 51 specimens of *swaini* had either embedded or exposed scales on the nape. In *nuchale* the nape is always naked mesially.

TABLE 5.

Comparison of Etheostoma **nuchale** *and E. swaini*[1]

Character	*E. nuchale*	*E. swaini*
Supratemporal canal	Widely interrupted	Complete
Infraorbital canal	Usually interrupted	Complete
Pored lateral-line scales	12-24	28-38
Unpored lateral-line scales	15-27	3-11
Dorsal spines	VIII-XI ($\bar{x}$ = 9.12)	X-XII ($\bar{x}$ = 10.70)
Total pectoral rays	22-24 ($\bar{x}$ = 23.29)	24-29 ($\bar{x}$ = 25.61)
Scales in transverse series	Usually 10 or 11	Usually 11 or 12
Scales around caudal peduncle	15-17 ($\bar{x}$ = 15.86)	16-19 ($\bar{x}$ = 17.18)

[1] All *E. swaini* from Black Warrior River system

Figure 2. Top. *Etheostoma swaini.* Adult male, 41.8 mm in standard length, from Black Warrior River system (UAIC 1184).
Bottom. *Etheostoma swaini.* Adult female, 44.7 mm in standard length, from Black Warrior River system (UAIC 1090).

Body proportions (Table 1) as well as visual comparisons (Figs. 1-2) show that *nuchale* is much more robust than the slender, stream-dwelling *swaini.* Since *nuchale* lives among dense growths of watercress where water movement is very slow, the deep, robust body is probably a habitat adaptation. A distinctive feature of *nuchale* is the humped nape which decurves sharply to the occiput. The humped nape does not seem to be associated with breeding activities since it is well-developed, even in juveniles of *nuchale.* It is absent in *swaini.* It is interesting to note that a few gravid females of *nuchale* were present in collections made from March through July. Under relatively constant environmental conditions of the spring, the breeding season of *nuchale* may be extended. We suspect that *swaini* of the Black Warrior River system breeds in early spring.

The following characters of *nuchale* probably represent increased specialization over those of *swaini*: (1) reduced number of pored lateral-line scales, (2) incomplete supratemporal canal, (3) incomplete infraorbital canal, (4) reduced number of pectoral rays and dorsal spines, (5) increased sexual dimorphism and dichromatism, and (6) highly specific habitat. *E. nuchale* has probably evolved, as an isolated population, in response to relatively constant conditions encountered in the spring environment.

Name.—The specific name, *nuchale,* "pertaining to the nape", calls attention to the light predorsal area and to the humped nape. The vernacular name, "watercress darter," is suggested in reference to its habitat.

Literature Cited

Bailey, R. M., and W. J. Richards. 1963. Status of *Poecilichthys hopkinsi* Fowler and *Etheostoma trisella,* new species, Percid fishes from Alabama, Georgia, and South Carolina. *Occ. Papers Mus. Zool. Univ. Mich.,* 630: 1-21.

Hubbs, C. L., and M. D. Cannon. 1935. The darters of the genera *Hololepis* and *Villora. Misc. Publ. Mus. Zool. Univ. Mich.,* 30: 1-93.

_____, and K. F. Lagler. 1958. Fishes of the Great Lakes region. Cranbrook Inst. Sci. Bull. 26: xiii + 213 p.

EARLY DEVELOPMENTAL STAGES OF THE ROCK SHRIMP, *SICYONIA BREVIROSTRIS* STIMPSON, REARED IN THE LABORATORY[1]

HARRY L. COOK
and
M. ALICE MURPHY,
Bureau of Commercial Fisheries, Galveston, Texas, U. S. A.

CONTENTS

		Page
I.	INTRODUCTION	109
II.	METHODS AND MATERIALS	110
III.	DESCRIPTION OF STAGES	110
	A. Egg	110
	B. Nauplius I	110
	C. Nauplius II	111
	D. Nauplius III	111
	E. Nauplius IV	111
	F. Nauplius V	111
	G. Protozoea I	112
	H. Protozoea II	115
	I. Protozoea III	115
	J. Mysis I	117
	K. Mysis II	118
	L. Mysis III	119
	M. Mysis IV	122
	N. Postlarva I	123
IV.	CHRONOLOGY OF LARVAL DEVELOPMENT	123
V.	COMPARISON WITH DEVELOPMENT OF OTHER *Sicyonia*	123
VI.	SUMMARY	126
VII.	LITERATURE CITED	126

ABSTRACT

Five nauplial, three protozoeal, four mysis, and the first postlarval stages of the rock shrimp, *Sicyonia brevirostris* Stimpson, reared from eggs spawned in the laboratory, are described and illustrated.

[1] Contribution No. 203, Bureau of Commercial Fisheries Biological Laboratory, Galveston, Texas.

I. INTRODUCTION

Fishery scientists at the Bureau of Commercial Fisheries Biological Laboratory in Galveston, Texas are studying the early life histories of Gulf of Mexico Penaeidae as part of an overall effort to establish relationships between the oceanic environment and the populations of commercially important shrimps. The effects of such variables as

EDITORIAL COMMITTEE FOR THIS PAPER:

WILLIAM W. ANDERSON, Laboratory Director, Bureau of Commercial Fisheries, U. S. Fish and Wildlife Service, Brunswick, Georgia

SHELDON DOBKIN, Assistant Professor of Zoology, Florida Atlantic University, Boca Raton, Florida

ROBERT M. INGLE, Director of Research, Division of Salt Water Fisheries, Florida Board of Conservation, St. Petersburg, Florida

temperature, salinity, and circulation, as well as the success of spawning, cannot be accurately assessed until specific identification of the various larvae is possible. The larvae of penaeid shrimps, especially during the nauplial stage, are remarkably similar, and at least 13 penaeid species occur in the northwestern Gulf of Mexico. To insure accurate identification of those larvae belonging to the genus *Penaeus*, the group of primary importance, we must also be able to distinguish the larval stages of associated noncommercial penaeids. This report describes the early development stages of one of these species, *Sicyonia brevirostris* Stimpson.

According to Lunz (1957), *S. brevirostris* occurs on the continental shelf of the western Atlantic from just south of Norfolk, Virginia, around the Gulf of Mexico to Yucatan. It appears to be confined inside the 50-fathom contour, reaching greatest abundance at 35 to 40 fathoms. At points throughout its range, this shrimp occurs in considerable numbers. It is not fished commercially, but since it has a very agreeable taste and attains a relatively large size, it is generally regarded as having potential commercial value.

II. Methods and Materials

All descriptions and figures are from specimens reared in the laboratory. Gravid females were caught at sea and transported to the laboratory. Spawning took place in a fiberglass aquarium that contained 80 liters of aerated, noncirculating sea water. The larvae were then maintained in the aquarium until the first postlarval stage was reached. Cultures of a diatom, *Skeletonema* sp., were added as food at the first protozoeal stage and brine shrimp, *Artemia* sp., were introduced at the first mysis stage.

Temperatures during rearing varied between 21.0° and 24.6° C. Salinity, which was 24.5‰ at the start, rose to a maximum of 27.4‰. The pH varied from 8.06 to 8.20.

Samples of larvae to be used for descriptive purposes were taken periodically and preserved in 5% buffered formalin. The unstained larvae were illustrated with the aid of a Camera Lucida. Dissection of the appendages was performed in formalin on a plastic slide.

The figures illustrating each substage depict an average larva. With the exception of the nauplial and protozoeal antennae, the appendages on these figures are intended to show only relative size and position, not setation or segmentation. To illustrate morphological details that would otherwise be obscured, we rotated the antennae of the nauplial substages on their axes. Figures of the mouth parts and other appendages represent a single appendage taken from one individual. In order to present a clearer figure, the setules on the setae were usually omitted. Measurements are given in mm.

The following abbreviations are used in the text: TL = total length, including the rostrum but excluding the caudal spines; W = mean width at the point of greatest width; CL = carapace length, including the rostrum; N = number of specimens.

The adult from which the larvae were obtained was identified according to Anderson and Lindner (1943) and Lunz (1945). Both the adult and the larvae have been deposited in the museum of the Bureau of Commercial Fisheries Biological Laboratory, Galveston, Texas.

III. Description of Stages

A. *Egg* (Fig. 1)

Viable eggs of *S. brevirostris* are round, golden brown in color, and translucent. Eggs measured soon after spawning were 0.23 mm in diameter. As the nauplius developed within the egg, the diameter increased to 0.27 mm just prior to hatching.

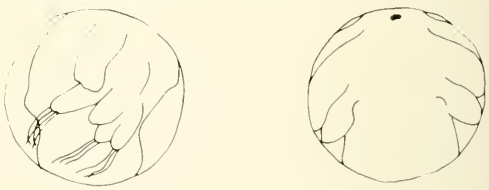


Figure 1. Late eggs showing developing nauplii. a. lateral view b. ventral view.

Hatching was observed only once. The nauplius filled the egg case and the furcal spines were already protruding when it was first noted. The nauplius appeared to flex, straightening out the first and second appendages and pushing the eggshell off the anterior end of its body.

B. *Nauplius I* (Fig. 2)

Mean TL = 0.30 mm (0.28-0.32 mm); W = 0.17 mm; N = 10

Nauplii of *S. brevirostris* exhibit the pyri-

form body that is typical of all penaeid larvae thus far described. A blunt labrum is present on the ventral surface and a slight protuberance arises from the dorsal surface of the body.

An ocellus, which is retained in subsequent nauplial substages, lies on the longitudinal axis of the body near the anterior end.

The posterior end of the body is rounded and bears a pair of spines.

Three pairs of appendages arise from the anterior portion of the body. The anterior ones (first antennae) are unbranched. The middle pair (second antennae) and third pair (mandibles) are branched into ventral endopods and dorsal exopods.

Setae arising from the appendages are smooth, but in succeeding substages the longer ones become plumose.

Color of the body and appendages is golden brown. The ocellus is black. Notes on color were not made for succeeding stages.

Setation of appendages:

First Antenna: Two short ventrolateral; a short spike and two long terminal; one long dorsolateral.

Second Antenna:

Endopod: Two short ventrolateral; two long terminal.

Exopod: Three long ventrolateral; two long terminal.

Mandible: Both branches bear three long setae.

C. *Nauplius II* (Fig. 3)

Mean TL = 0.31 mm (0.29-0.34 mm);
W = 0.18 mm; N = 7

The body is slightly more elongate than in the preceding substage. The posterior portion (edge) of the body between the single pair of caudal spines becomes flattened.

Setation of appendages:

First Antenna: Two short ventrolateral; one short, one long, and one medium terminal; one short dorsolateral.

Second Antenna:

Endopod: Two short ventrolateral; two long terminal.

Exopod: Three long ventrolateral; two long and one short terminal.

Mandible: Unchanged from Nauplius I.

D. *Nauplius III* (Fig. 4)

Mean TL = 0.35 mm (0.32-0.37 mm);
W = 0.18 mm; N = 26

The body is more elongate than in Nauplius II. Faint folds, the beginnings of ventral appendages, can be seen posterior to the labrum. The bases of the mandibles have become slightly swollen. A depression is present between the three pairs of caudal spines.

Setation of appendages:

First Antenna: One short and two medium ventrolateral; one medium, one long, and one short terminal.

Second Antenna:

Endopod: Two short ventrolateral; one short and two long terminal.

Exopod: Four long ventrolateral; two long and one short terminal.

Mandible: Unchanged from Nauplius I.

E. *Nauplius IV* (Fig. 5)

Mean TL = 0.37 mm (0.33-0.40 mm);
W = 0.18 mm; N = 30

The body has become longer and the posterior portion more slender. The ventral appendages that were first noted in the preceding substage are more prominent, though still beneath the cuticle. These are the first and second maxillae and first and second maxillipeds. Two definite lobes have been formed at the posterior end of the body, each bearing five caudal spines.

Setation of appendages:

First Antenna: Two long and one medium ventrolateral; two long and one short terminal; one short dorsolateral.

Second Antenna:

Endopod: Two short ventrolateral; one long and two medium terminal.

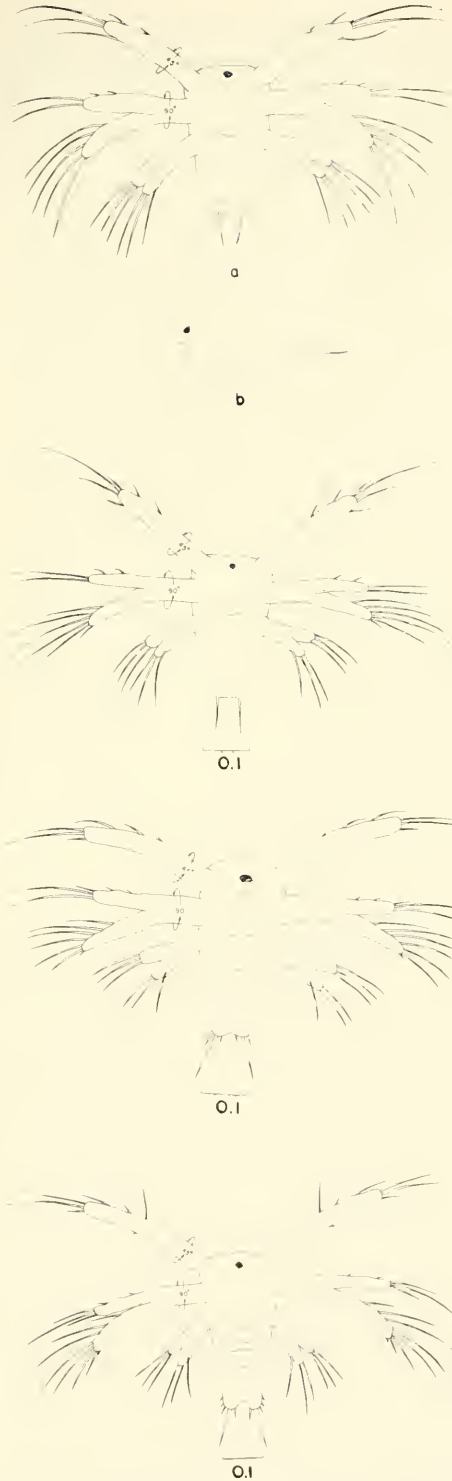
Exopod: One medium and three long ventrolateral; two long, one medium, and one short terminal.

Mandible: Unchanged from Nauplius I.

F. *Nauplius V* (Fig. 6)

Mean TL = 0.44 mm (0.38-0.46 mm);
W = 0.18 mm; N = 46

The body is further elongated and the furcal processes are more pronounced, each giving rise to seven spines. The maxillae and maxillipeds are now external, and show more advanced development. The swelling at the base of the mandible, which has become large and prominent, possesses a masticatory surface composed of several rows of small teeth. Both the endopod and exopod of the mandible are frequently hollow and transparent. The outline of a developing carapace



Figures 2-5, top to bottom. 2. Nauplius I. a. ventral view b. lateral view. 3. Nauplius II, ventral view. 4. Nauplius III, ventral view. 5. Nauplius IV, ventral view.

can be seen on the dorsal surface of the body, and frontal organs are present on its anterior margin.

Setation of appendages:

First Antenna: Two short and one medium ventrolateral; two long, one medium, and two short terminal; two short dorsolateral.

Second Antenna:

Basis: One short ventrolateral.

Endopod: Two medium and two short ventrolateral; one short and three long terminal.

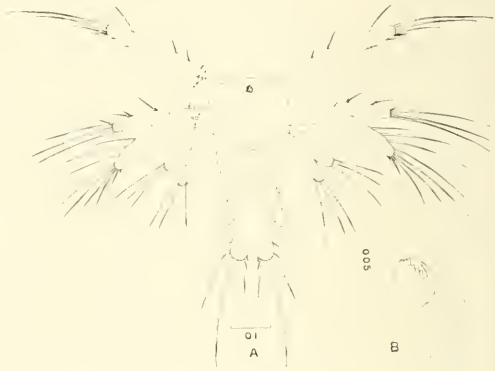


Figure 6. Nauplius V. A. ventral view B. base of mandible.

Exopod: Four long ventrolateral; three long, one medium, and one short terminal.

Mandible: Unchanged from Nauplius I.

G. *Protozoea I* (Fig. 7)

Mean TL = 0.81 mm (0.70-0.99 mm); mean CL = 0.33 mm (0.30-0.36 mm); N = 39

Body shape changes considerably with the molt to the first protozoeal substage. A large, loose-fitting carapace covers the anterior section of the body. The posterior portion of the body has lengthened greatly and is now distinctly segmented. The maxillae and first and second maxillipeds are well developed and functional.

The carapace is rounded with a median notch at the anterior end, a pair of rounded frontal organs being the only protuberances on it. The ocellus, which persists in subsequent protozoeal substages, is present between a pair of compound eyes that are visible beneath the carapace. The labrum does not bear a spine on its anterior margin. Two lobes of the labium, bearing short bristles on their inner margins, can be seen posterior to the labrum. Several teeth of the

inwardly projecting mandibles can be seen between the labrum and labium.

The first antenna is approximately twice the length of the endopod of the second antenna. It is composed of three major segments. The basal segment, which is divided into five subsegments, bears one short seta. The second segment bears three setae, one short and one medium ventrolateral, and one short posterolateral. The disal segment bears three long and two short terminal, and one short posterolateral, setae.

The second antenna is composed of a two-segmented protopod, an endopod of two segments, and an exopod of from seven to nine, frequently indistinct, segments. The protopod bears one seta at the juncture with the endopod. The first segment of the endo-

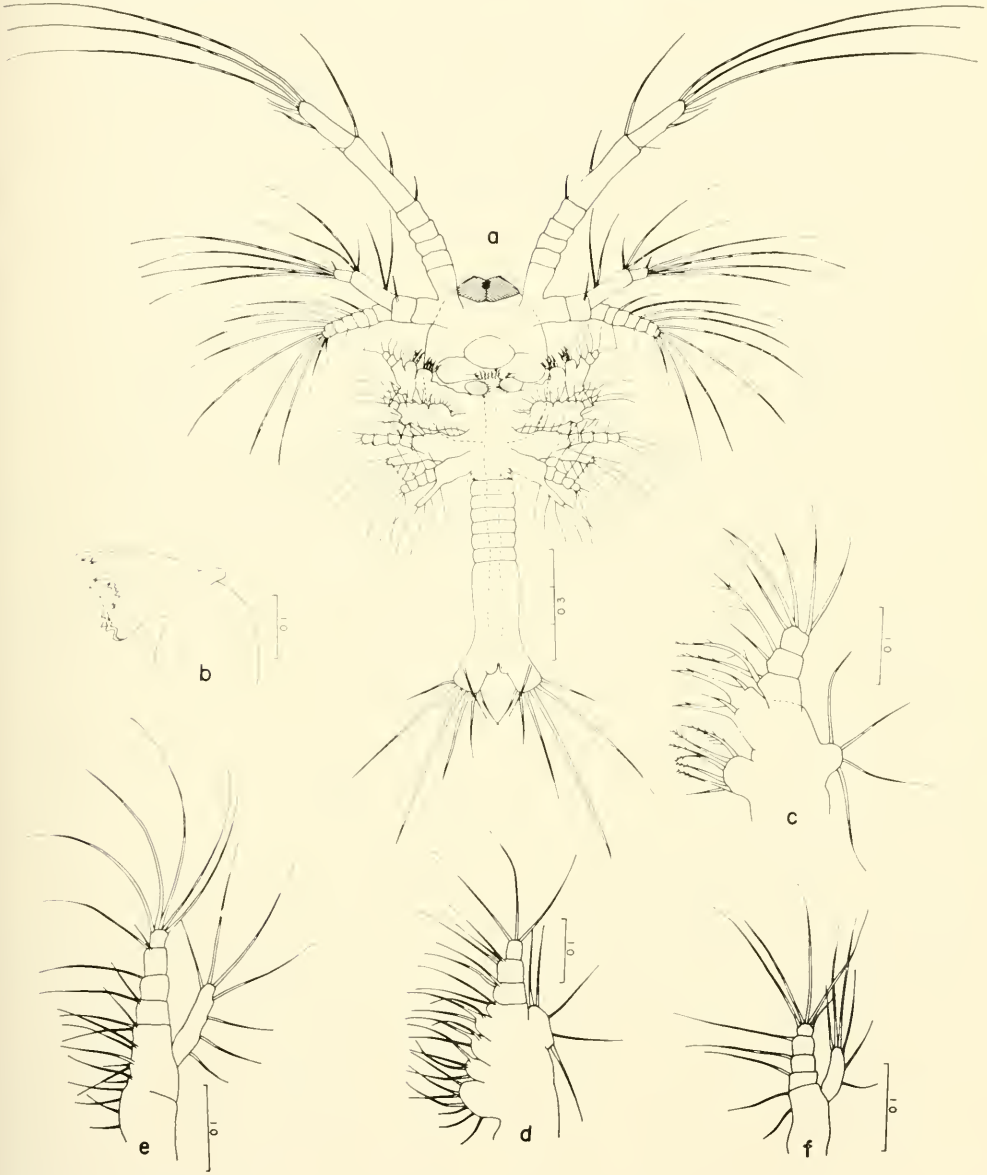


Figure 7. Protozoea I.

a. Ventral view
b. Mandible
c. Maxilla I
d. Maxilla II
e. Maxilliped I
f. Maxilliped II

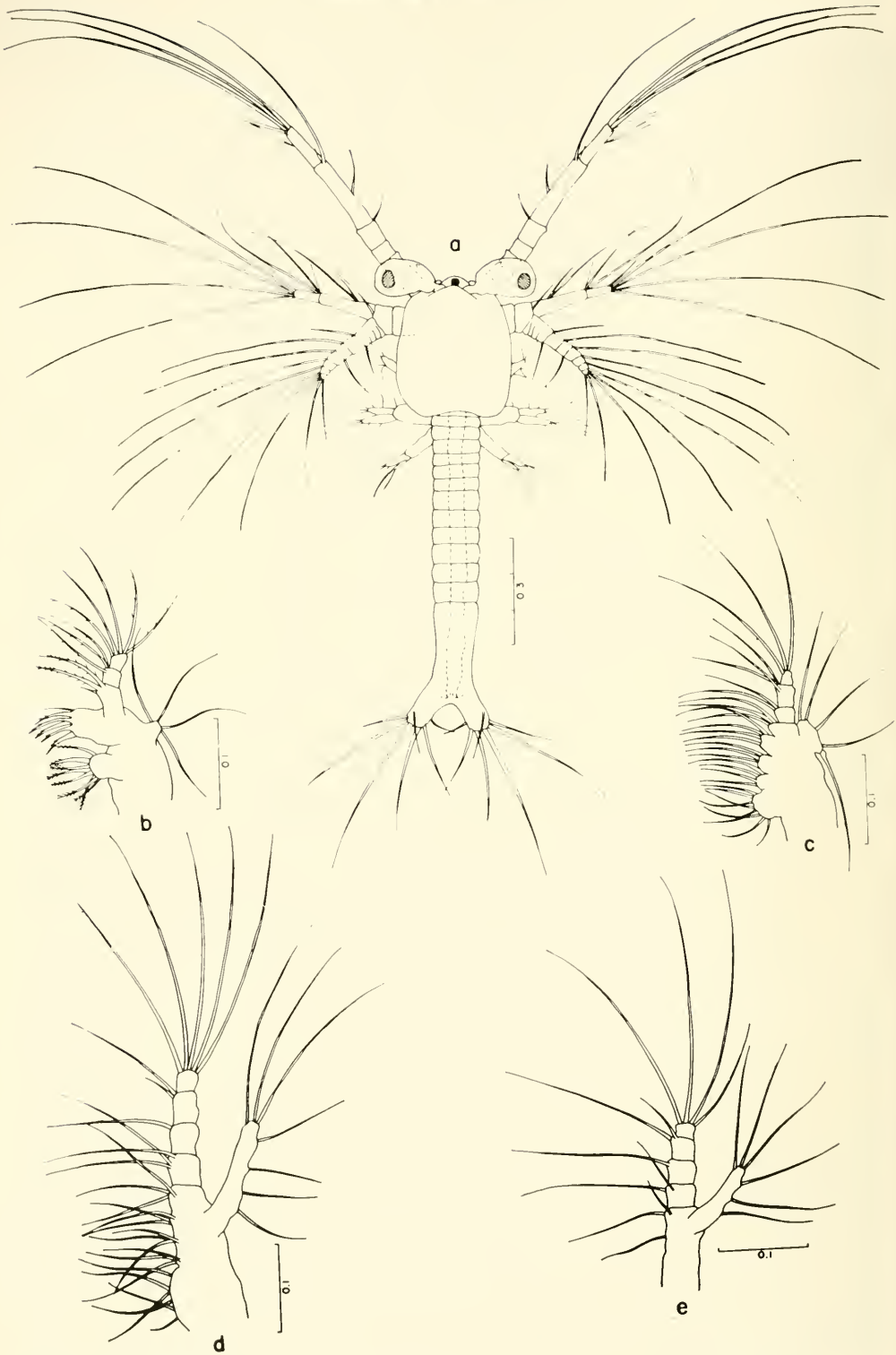


Figure 8. Protozea II.

a. Dorsal view
b. Maxilla I
c. Maxilla II
d. Maxilliped I
e. Maxilliped II

pod gives rise to a pair of setae from a point about one-third the length of the segment, and three terminal setae. The distal segment bears five terminal setae. The exopod bears five setae on its ventrolateral and two on its dorsolateral margins, as well as five terminal setae.

The mandible has lost both the endopod and exopod. The masticatory process is longer than in the last nauplial substage and curves inward, terminating in a ring of teeth.

The first maxilla consists of an unsegmented protopod, a three-segmented endopod, and a small knoblike exopod. The protopod has two large lobes, each giving rise to several stout, toothed spines. The first and second segments of the endopod each bear two setae, and the third five. The exopod bears four setae.

The second maxilla is comprised of an unsegmented protopod, a three-segmented endopod and a small knoblike exopod. The protopod has five lobes on its ventral margin, the basal lobe bears about seven setae and the remainder two to five. The first segment of the endopod bears two setae, the second and third, three; the exopod bears five.

The first maxilliped is longer than the maxillae and is biramous. It is composed of an unsegmented protopod, a four-segmented endopod, and an unsegmented exopod. The protopod has from 13 to 15 setae on its ventral margin. The first and third segments of the endopod each bear two setae; the second, one; and the fourth, five. The exopod bears four lateral and three terminal setae.

The second maxilliped greatly resembles the first, although it is somewhat smaller. The protopod bears two setae. The first three segments of the endopod each bear one seta and the fourth bears five. The exopod has three lateral and three terminal setae.

The third maxilliped is small, biramous, and usually does not bear setae.

The slender posterior portion of the body is divided into six thoracic segments and an unsegmented abdomen. The abdomen terminates in a well-developed, forked, telson, each lobe of which bears seven spines, the outermost etxending inward across the furca.

H. *Protozoea II* (Fig. 8)

Mean TL = 1.23 mm (1.12-1.44 mm);
mean CL = 0.44 mm (0.38-0.45 mm);
N = 28

The second protozoea is characterized by the presence of stalked compound eyes, a segmented abdomen, and a small rostrum which does not extend to the anterior edge of the body.

The frontal organs have been lost and do not reappear in later substages. Small papillae which are present on the dorsoanterior margins of the eyes persist in the third protozoeal substage.

Segmentation of the appendages remains almost unchanged from the preceding substage. A dorsolateral seta has been added to the terminal segment of the first antenna. The number of spines on the second lobe of the protopod of the first maxilla has increased and an additional short seta is found on both the first and second segments of the endopod. Three setae have been added to the second maxilliped, one on the protopod and two on the endopod. Rudiments of five pairs of pereiopods are present posterior to the maxillipeds.

The abdomen is divided into six segments with the telson still part of the sixth. The number of caudal spines remains constant at seven pairs.

I. *Protozoea III* (Fig. 9)

Mean TL = 1.96 mm (1.84-2.09 mm);
mean CL = 0.58 mm (0.54-0.61 mm);
N = 20

This substage can be distinguished from the second protozoea by the presence of biramous uropods and spines on the abdominal segments.

The rostrum has undergone slight elongation and now extends slightly past the anterior margin of the body.

The five subsegments which made up the basal segment of the first antenna in preceding protozoeal substages have combined and three are now four segments. The first segment gives rise to one seta; the second and third, two; and the fourth, seven. In addition to the two more prominent setae, a variable number of small setae now rim the distal portion of the third segment.

The second antenna, maxillae, and second and third maxillipeds remain essentially the same as in the preceding substage. The seta on the second segment of the endopod of

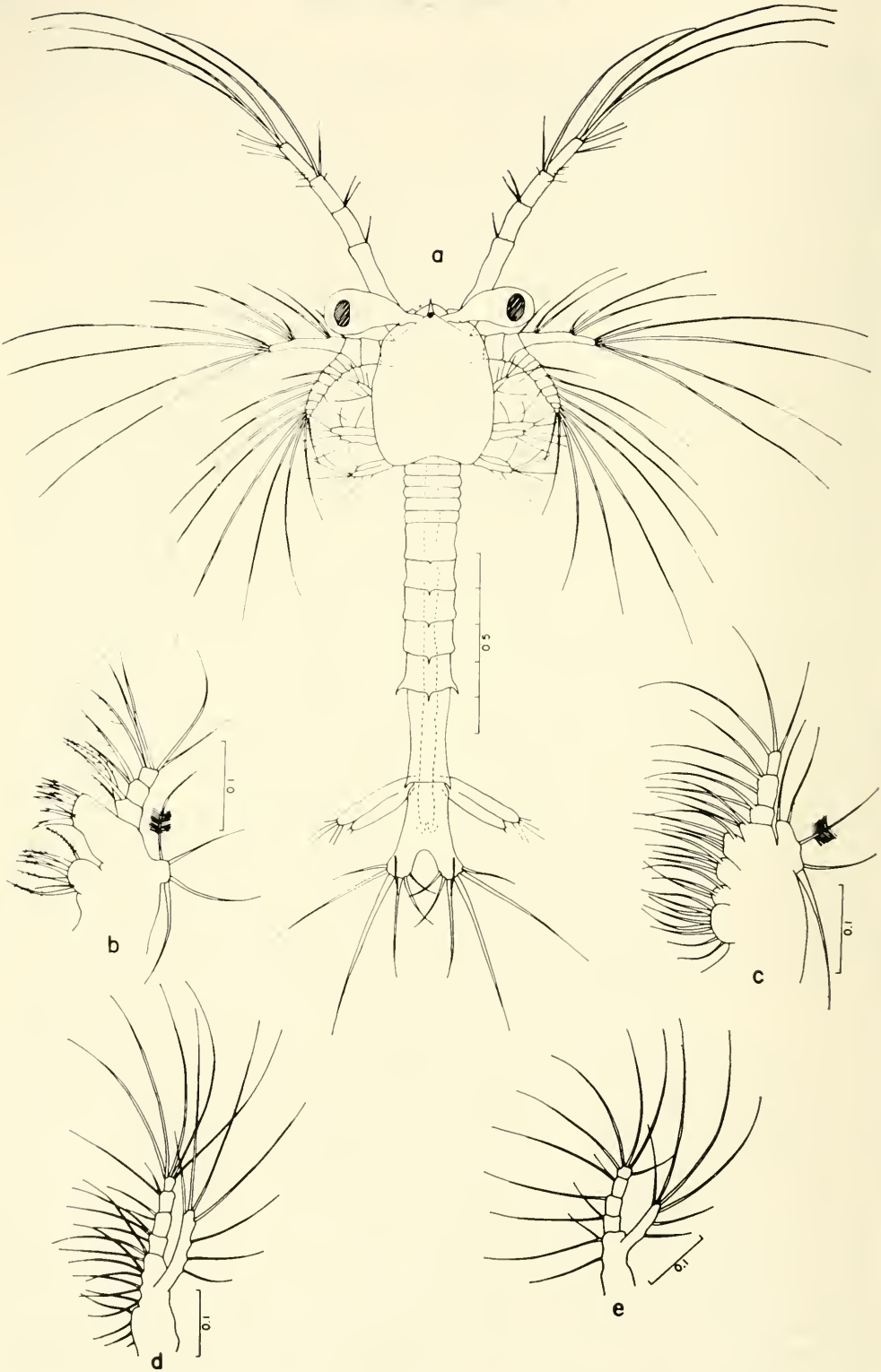


Figure 9. Protozoea III.

a. Dorsal view
b. Maxilla I
c. Maxilla II
d. Maxilliped I
e. Maxilliped II

the first maxilla in the preceding substage has been lost. Such condition might indicate a variable number of setae on this segment. A second seta is present on the second segment of the endopod of the first maxilliped. Although the pereiopods have developed further and are biramous, they are still nonfunctional.

Segmentation of the abdomen is more distinct in this substage. Each of the first five segments bears a median spine on its dorsoposterior border. The fifth segment also has a pair of posterolateral spines, as does the sixth.

The telson is now separated from the sixth segment and each lobe retains seven caudal spines. A pair of biramous uropods originate from the ventroanterior margin of the telson. The exopod is slightly longer than the endopod and five or six setae arise from its apex. The endopod usually has two very small terminal setae.

J. *Mysis I* (Fig. 10)
Mean TL = 2.47 mm (2.16-2.66 mm);
mean CL = 0.82 mm (0.74-0.89 mm);
N = 24

At the molt to the first mysis substage, the larva undergoes another fundamental modification in body form, taking on a semblance of the adult for the first time. The transfiguration is exemplified in the functional pereiopods with their long brushlike exopods, and by the transformation of the first and second antennae into the adult shape.

The carapace has a short rostrum that extends slightly less than half the length of the eye. A single spine is found on the dorsal carina of the carapace. Supraorbital and pterygostomian spines are present.

The ocellus and occular papillae persist in this and succeeding mysis substages.

The first antenna consists of three segments. The first segment, which is about twice the length of the second and third combined, bears two spines, one on its median margin, and one on its lateral margin. The distal segment gives rise to two branches; the lateral, bearing five or six setae, is three times as long as the median, which bears a single seta. A series of setae are present along the margins of the appendage, and numerous setae arise from the apex of each segment.

The second antenna is composed of a two-segmented protopod (the basal segment is not shown in fig. 10), an unsegmented endopod with two lateral and three terminal setae, and an unsegmented, flattened exopod which bears 10 setae along its median and apical margins as well as a single, subterminal, externolateral seta.

The mandible has undergone no appreciable change. A short spine, added at the base of the second lobe of the protopod of the first maxilla, is the only difference. The exopod of the second maxilla has enlarged and now bears nine setae. An additional seta is present at both the apex of the protopod and on the endopod of the first maxilliped. The first and second segments of the endopod of the second maxilliped have each gained two setae, and two lateral setae have been lost from the exopod.

The third maxilliped and five pereiopods have become enlarged and possess long unsegmented exopods which bear six to eight setae. The protopod of the third maxilliped is unsegmented and bears four setae. Its endopod is composed of four segments, the first giving rise to one seta; the second, none; the third, three; and the fourth, five. The protopod of the first pereiopod is two-segmented with only a single seta present on the second segment. The endopod of the first pereiopod has been modified to form a rudimentary chela bearing three setae. The other four pereiopods were not examined in detail.

A ventromedian spine arises from each of the first five abdominal segments; the pleura, however, normally do not bear spines. Infrequently, laboratory-reared mysis exhibited dorsoposterior spines on the fourth, fourth and fifth, or fifth segments. Since examination of *Sicyonia* mysis from the plankton has failed to yield a specimen with dorsoposterior spines, their presence is tentatively regarded as an abnormal condition. The sixth segment possesses a dorsomedian spine and a pair of posterolateral spines.

The uropod has developed an unsegmented protopod which bears a posteroventral and a posterolateral spine. The endopod and exopod are of equal length and bears numerous setae on their margins.

The telson, deeply cleft, bears six pairs of terminal and subterminal spines, and a single pair of lateral spines.

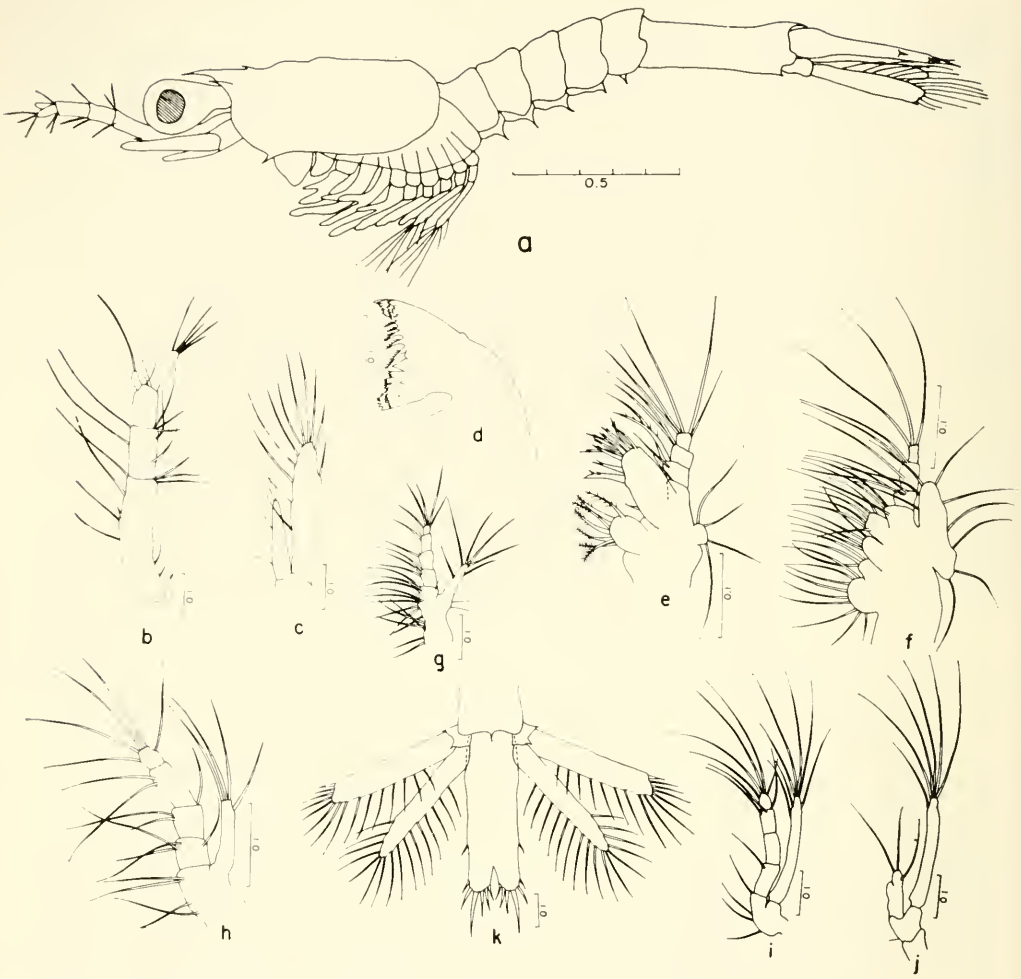


Figure 10. Mysis I.

a. Lateral view
b. Antenna I
c. Antenna II
d. Mandible
e. Maxilla II
f. Maxilla II
g. Maxilliped I
h. Maxilliped II
i. Maxilliped III
j. Periopod I
k. Telson

K. *Mysis II* (Fig. 11)

Mean TL = 2.89 mm (2.70-3.15 mm);
mean CL = 0.96 mm (0.90-1.05 mm);
N = 13

A second spine is added to the dorsal carina of the carapace and there is now a well-developed antennal spine.

The first antenna remains unchanged, except that the developing statocyst can now be seen at the base of the appendage. The exopod of the second antenna now possesses a subterminal spine on its lateral margin and the number of median and apical setae has increased to 13.

The mandible bears a large unsegmented palp. An exopod is no longer present on the first maxilla, and a seta has been lost from the second segment of the endopod. The endopod of the second maxilla has become further enlarged and the number of setae has increased to 24.

The protopods of the three maxillipeds are composed of two segments. The terminal seta added to the protopod of the first maxilliped in the last substage is no longer present. The first segment of the endopod has also lost a seta. The endopod of the second maxilliped has gained a terminal seta.

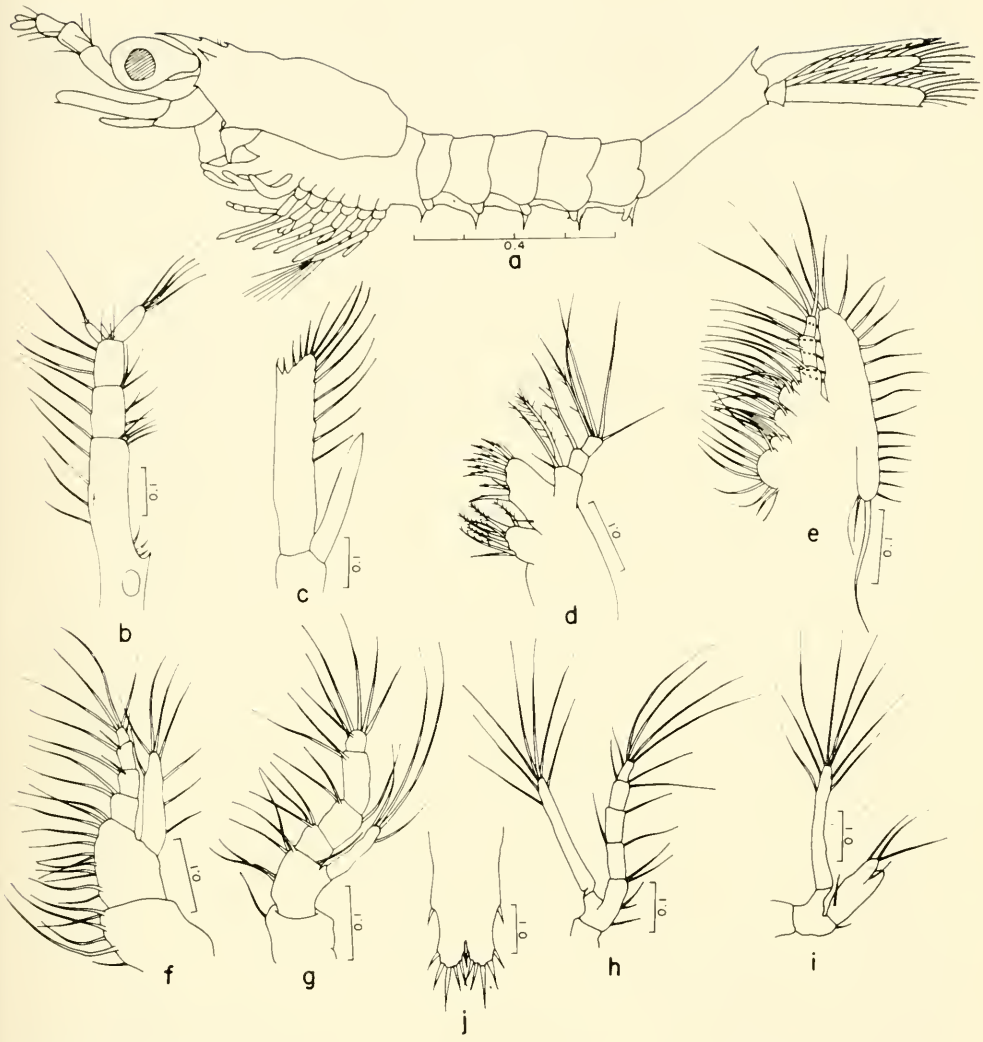


Figure 11. Mysis II

a. Lateral view
b. Antenna I
c. Antenna II
d. Maxilla I
e. Maxilla II
f. Maxilliped I
g. Maxilliped II
h. Maxilliped III
i. Pereiopod I
j. Telson

A single seta has been added to both the first and second segments of the endopod of the third maxilliped. The chela of the first pereiopod now bears six setae. Rudiments of the branchiae are present as small lobes on the maxillipeds and pereiopods.

The addition of small unsegmented pleopods and a reduction in the width of the cleft in the telson represent the only major changes in the posterior portion of the body.

L. *Mysis III* (Fig. 12)

Mean TL = 3.51 mm (2.94-3.72 mm);
mean CL = 1.13 mm (0.90-1.26 mm);
N = 18

An additional spine added to the dorsal carina of the carapace raises the count to three.

The antenna have been modified slightly; the basal segment of the first antenna has gained a lateral spine apically, the endopod

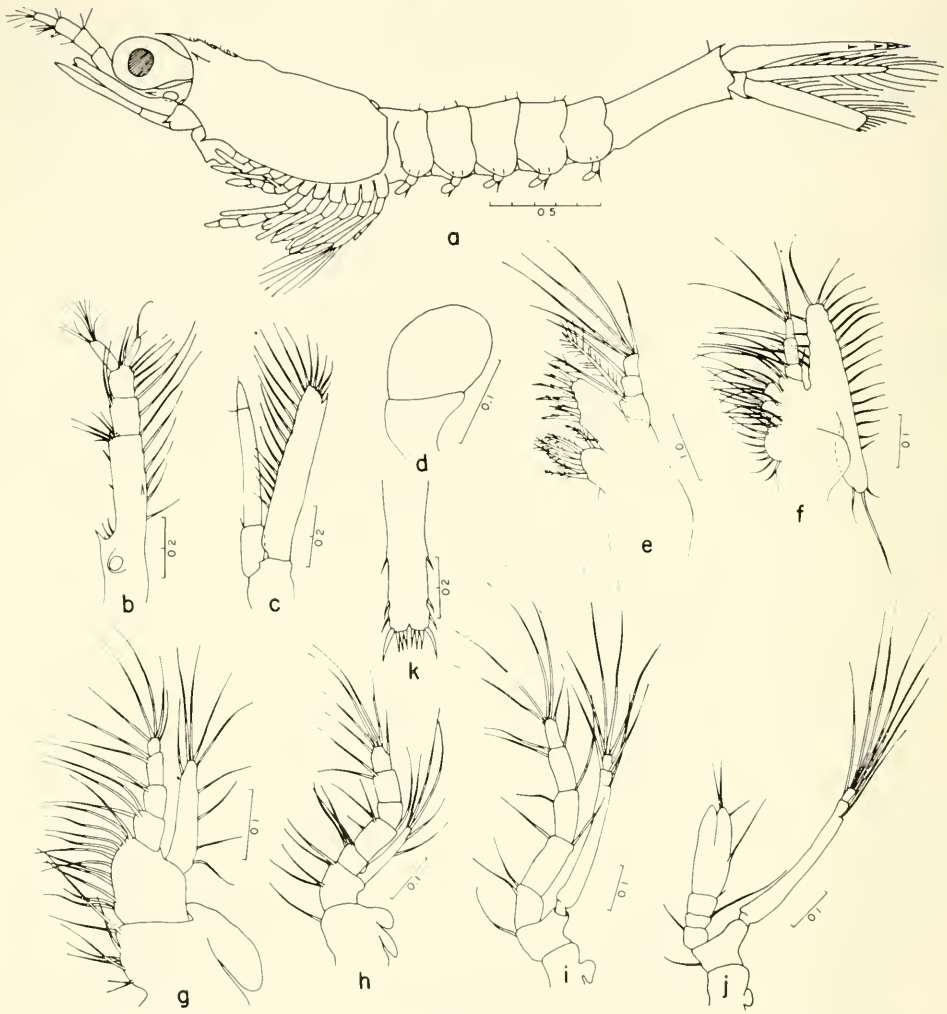


Figure 12. Mysis III.

a. Lateral view
b. Antenna I
c. Antenna II
d. Mandibular palp
e. Maxilla I
f. Maxilla II
g. Maxilliped I
h. Maxilliped II
i. Maxilliped III
j. Pereiopod I
k. Telson

of the second antenna is now made up of three segments and its exopod bears 19 setae.

The mandibular palp, composed of two segments, has enlarged further. The maxillae remain essentially unchanged from the preceding substage. Rudiments of the gills are present on the three maxillipeds and first pereiopod.

A seta has been added to both the first segment of the endopod and to the exopod of the first maxilliped. The endopod of the second maxilliped has gained an additional segment which does not bear setae. The distal segment of its protopod has lost two setae, leaving the protopod with one seta, while the exopod and the second segment of the endopod each have an additional seta. The endopod of the third maxilliped has gained a segment, making a total of five. The first three segments of the endopod now possess two setae each; the fourth segment, three; and the fifth, five. The exopod of the third maxilliped and of each pereiopod is now composed of two segments. The endopod of the first pereiopod is composed of four segments, with the distal segment being the

rudimentary chela.

The posterior portion of the body has changed little. The pleopods, although now two-segmented, are still small. The cleft in the telson has become greatly reduced in size and the position of the spines has changed. There are now four pairs of terminal and three pairs of lateral spines. The postero-ventral spine on the protopod of the uropod is absent.

Figure 13. Mysis IV.

a. Lateral view
b. Antenna I
c. Antenna II
d. Mandible
e. Maxilla I
f. Maxilla II
g. Maxilliped I
h. Maxilliped II
i. Maxilliped III
j. Periopod I
k. Telson

M. *Mysis IV* (Fig. 13)
Mean TL = 3.68 mm (3.48-3.81 mm);
mean CL = 1.20 mm (1.11-1.23 mm);
N = 10

The fourth mysis differs only slightly from the preceding substage. The addition of a fourth rostral spine and a reduction in the cleft of the telson represent the most prominent modifications. The antennae have also undergone changes, with the endopod of the first antenna now composed of two segments, and that of the second, five segments.

The distal segment of the endopod of the first maxilla has lost a seta. The number of setae on the exopod of the second maxilla has increased to 36 and, although not shown in Fig. 13f, the setation of the protopod and exopod remains unchanged. The second and fourth segments of the endopod of the first maxilliped have each lost a seta, and the exopod, two. The number of setae on the protopod of the second maxilliped, and that of the second and fifth segments of its endopod, has increased and decreased by

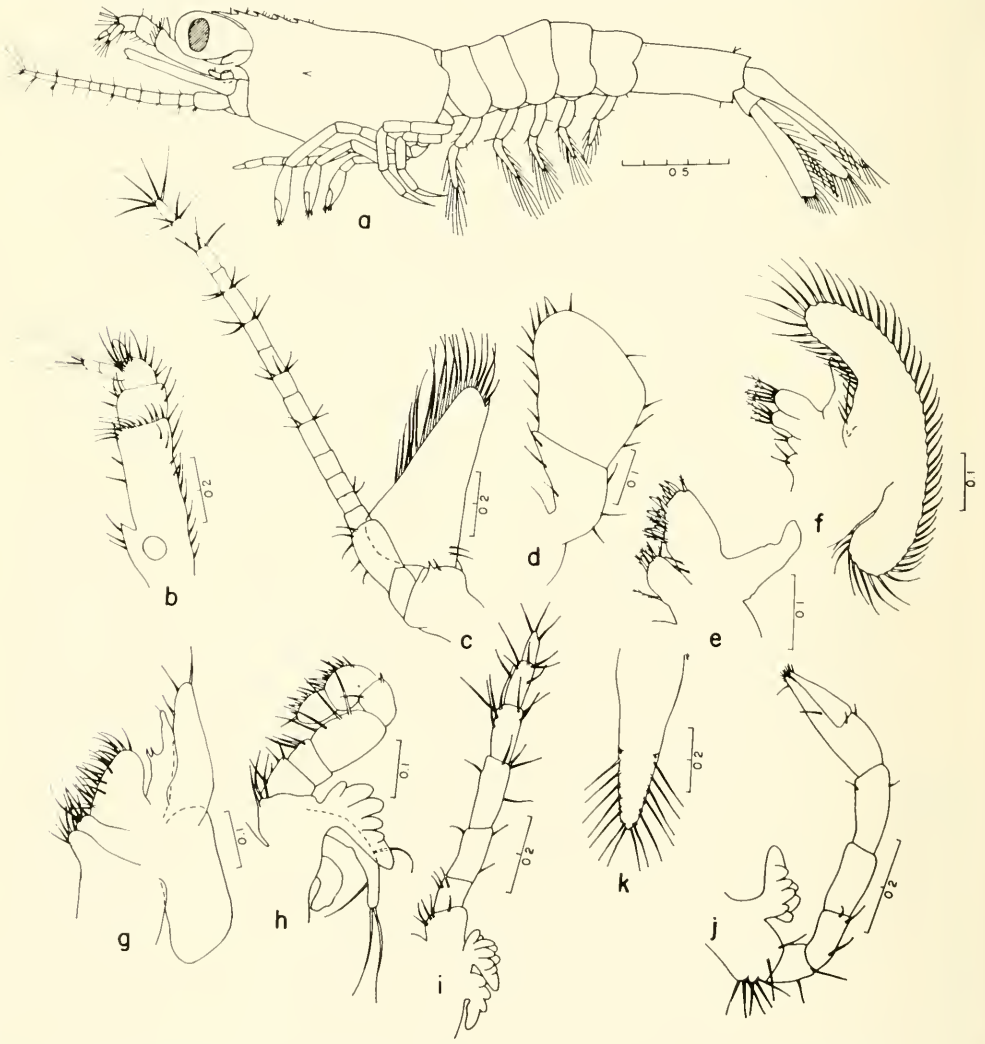


Figure 14. Postlarva I.

a. Lateral view
b. Antenna I
c. Antenna II
d. Mandibular palp
e. Maxilla I
f. Maxilla II
g. Maxilliped I
h. Maxilliped II
i. Maxilliped III
j. Pereiopod I
k. Telson

one, respectively; its exopod is now two-segmented.

The pleopods retain essentially the same shape, but have increased in length and are now about one and one-half times the length of those of the previous substage.

N. *Postlarva I* (Fig. 14)
Mean TL = 3.87 mm (3.51-4.35 mm);
mean CL = 1.13 mm (1.07-1.21 mm);
N = 9

With the molt to postlarva, the exopods are lost from the pereiopods and the pleopods, now heavily setose, are the principal swimming organs.

The rostrum is short, extending about one-half the length of the eye. The carapace usually bears four teeth on its dorsal carina, although some specimens show a small fifth spine anteriorly. Hepatic and antennal spines are present, the supraorbital and pterygostomian spines having been lost.

The ocellus persists, but the ocular papillae are no longer present.

Although there is no appreciable change in the first antenna, the endopod (flagellum) of the second antenna is elongate and composed of 16 segments, while the exopod (antennal blade) is very broad at its base.

The mandibular palp has increased in size and bears about 20 setae along its margin. The endopod of the first maxilla is reduced greatly and is no longer setose. The endopod of the second maxilla is also vestigial, and the spines on the four lobes of the protopod are less prominent. The exopod has enlarged greatly and possesses about 60 setae.

Both the endopod and exopod of the first maxilliped are greatly reduced in size and setation. The second maxilliped retains a greatly reduced exopod, while the third maxilliped and the pereiopods have lost their exopods. The second maxilliped has become recurved and bears numerous spinelike setae on the last two segments. The dactyls of the chelipeds are fully formed. Although still rudimentary, the branchiae on the maxillipeds and pereiopods have developed two rows of small protuberances on their external surfaces.

The first five abdominal segments do not possess spines. The sixth segment has a small dorsomedian and a small pair of posterolateral spines.

The uniramous pleopods have lengthened and bear about 12 setae on the second segment.

The protopod of the uropod retains a small posterolateral spine. The endopod and exopod are of equal length.

The telson is no longer cleft, ending instead in a blunt point. It bears five pairs of minute lateral spines and seven pairs of setae.

IV. Chronology of Larval Development

Experiments by the authors with larvae of the brown shrimp, *Penaeus aztecus* Ives, showed that growth is closely related to temperature, becoming more rapid the warmer the water. Consequently, it is likely that the growth of *S. brevirostris* would also be accelerated at temperatures higher than those encountered during this rearing trial (21.0° to 24.6° C).

In this study, the eggs were spawned at night and hatched the following afternoon. Each nauplial substage lasted approximately 12 hours. The number of days after spawning when the indicated substages were first noted are listed in Table I.

Table 1
Chronology of larval development

Substage	Days after spawning
Protozoea I	3
Protozoea II	6
Protozoea III	10
Mysis I	12
Mysis II	16
Mysist III	22
Mysis IV	24
Postlarva 1	29

V. Comparison With Development of Other *Sicyonia*

As has been described, the larvae of *S. brevirostris* pass through five nauplial, three protozoeal, and four mysis substages before molting to the first postlarval stage. This sequence differs from that of the larval development of other (littoral) penaeidae in the northern Gulf area, most of which pass through only three mysis substages (Cook, in press), as well as from that of larvae of other *Sicyonia* spp. described in the literature (Table 2). One reason for the variation among descriptions by different authors may be that the number of substages is influenced by the environment in which the larvae grow. For example, Pike and Williamson (1964)

TABLE 2

Major differences between corresponding substages of four species of Sicyonia larvae[1]

Stage and structure	*S. brevirostris*	*S. stimpsoni*	*S. wheeleri*	*S. carinata*
Nauplius I				Heldt attributes 8 naupliar substages to *S. carinata*. As illustrations of all substages are not given and setation is not described in detail, we have not attempted to compare this species with the other three. Length of the first nauplius is 0.26 mm and that of the last is 0.38 to 0.40 mm.
Length (mm)	0.30 (0.28-0.32)	0.24-0.26	See footnote 2	
Antenna II				
Endopod	2 lateral and 2 terminal setae	No lateral and 2 terminal setae		
Exopod	5 setae	4 setae		
Caudal spines	1 pair	1 pair		
Nauplius II				
Length (mm)	0.31 (0.29-0.34)	0.26-0.30	0.28	
Antenna II				
Endopod	2 lateral and 2 terminal setae	No lateral and 3 terminal setae	No lateral and 2 terminal setae	
Exopod	6 setae	5 setae	6 setae	
Caudal spines	1 pair	1 or 2 pairs	1 pair	
Nauplius III				
Length (mm)	0.35 (0.32-0.37)	0.30-0.36	0.34-0.37	
Antenna II				
Endopod	2 lateral and 3 terminal setae	No lateral and 4 terminal setae	No lateral and 3 terminal setae	
Exopod	7 setae	6 setae	7 setae	
Caudal spines	3 pairs	2 or 3 pairs	3 pairs	
Nauplius IV				
Length (mm)	0.37 (0.33-0.40)	0.36-0.40	See footnote 2	
Antenna II		No lateral and 4 terminal setae		
Endopod	2 lateral and 3 terminal setae	7 setae		
Exopod	8 setae	6 or 7 pairs		
Caudal spines	5 pairs			
Nauplius V				
Length (mm)	0.44 (0.38-0.46)	0.36-0.42	0.4	
Antenna I	2 long terminal setae	2 long terminal setae	3 long terminal setae	
Antenna II				
Endopod	5 lateral and 4 terminal setae	1 lateral and 3 terminal setae	4 lateral and 4 terminal setae	
Exopod	9 setae	8 setae	8 setae	
Caudal spines	7 pairs	7 pairs	6 pairs	
Protozoea I				
Length (mm)	0.81 (0.70-0.99)	0.70-0.80	0.7-0.75	0.76-0.86
Antenna I	5 terminal and 1 dorsolateral setae	4 terminal and no dorsolateral setae	5 terminal and 1 dorsolateral setae	5 terminal and 1 dorsolateral setae
Antenna II				
Endopod	1+2+3 lateral setae[3]	2+2 lateral setae	1+2 lateral setae	1+1+2 lateral setae

Protozoea II				
Length (mm)	1.23 (1.12-1.44)	1.0	1.02	1.23-1.30
Antenna I	5 terminal and 2 dorsolateral setae	5 terminal and no dorsolateral setae	5 terminal and 1 dorsolateral setae	5 terminal and 1 dorsolateral setae
Antenna II				
Endopod	1 + 2 + 3 lateral setae	2 + 2 lateral setae	1 + 2 lateral setae	1 + 2 + 2 lateral setae
Protozoea III				
Length (mm)	1.96 (1.84-2.09)	1.36-1.68	1.32-1.5	[not given]
Antenna II				
Endopod	1 + 2 + 3 lateral setae	2 + 2 lateral setae	1 + 2 lateral setae	1 + 2 + 2 lateral setae
Abdomen	First 5 segments with spine on dorsoposterior border, 1 pair of posterolateral spines present on both the fifth and sixth segments	Dorsoposterior spine present only on third, fourth, and fifth segments; no posterolateral spines on fifth or sixth segments	First 5 segments with spine on dorsoposterior border; 1 pair of posterolateral spines on fifth segment and 2 pairs on the sixth	First 5 segments with spine on dorsoposterior border; 1 pair of posterolateral spines on fifth segment and none on the sixth
Mysis I				
Length (mm)	2.47 (2.16-2.66)	See footnote 4	1.66	2.05-2.39
Abdomen	Ventral margins of pleura of first 5 segments rounded; a pair of posterolateral spines on sixth segment		Ventral margins of pleura of first 4 segments pointed	Ventral margins of pleura of first 5 segments rounded; no posterolateral spines on sixth segment
Mysis II		2.0-2.8	1.8	2.6-2.8
Length (mm)	2.89 (2.70-3.15)	Ventral margins of pleura of first 5 segments pointed	Ventral margins of pleura of first 3 segments pointed	Same as in Mysis I
Abdomen	Same as in Mysis I			
Mysis III				
Length (mm)	3.51 (2.94-3.72)	2.8-3.6	2.37	2.95-3.04
Abdomen	Same as in Mysis I	Ventral margins of pleura of first 5 abdominal segments pointed; point arises from the middle of the segment on all segments	Ventral margins of pleura of first 5 segments pointed; point arises from the posterior portions on segments 3-5	Same as in Mysis I
Mysis IV				
Length (mm)	3.68 (3.48-3.81)	None recorded	None recorded	3.26
Abdomen	Same as in Mysis I			Same as in Mysis I

[1] Data on *S. stimpsoni* from Pearson (1939), on *S. wheeleri* from Gurney (1943), and on *S. carinata* from Heldt (1938).

[2] Gurney (1943) lists only three nauplial substages but concedes that he may have missed some. We have arbitrarily placed his nauplii into the second, third, and fifth substages as they appear similar to corresponding substages of both *S. brevirostris* and *S. stimpsoni*.

[3] The number of setae at each point of insertion is recorded starting proximally.

[4] Pearson (1939) recorded only two mysis substages, which we believe correspond to Myses II and III of the other species.

found that under certain conditions, larvae of *Pandalus montagui* Leach reared in the laboratory passed through several additional zoeal substages before molting to megalopa. To ensure that the number of substages listed for *S. brevirostris* in this paper is the same as occurs in nature, and was not affected by the rearing procedure, a comparison was made with *Sicyonia* larvae in plankton samples. The number of substages found in a large volume of planktonic material was the same as that found among laboratory-reared larvae.

Larvae of three other species of *Sicyonia* have been described: *S. carinata* by Heldt (1938); *S. stimpsoni* by Pearson (1939); and *S. wheeleri* by Gurney (1943). Upon comparing descriptions of these larvae with specimens of *S. brevirostris,* we determined that in the protozoeal and mysis stages they possess morphological characters which permit their differentiation both from other penaeid larvae and from each other. Variation between nauplii of different *Sicyonia* often appears to be as great as that observed between penaeid genera at the nauplial stage, and there seemingly are no definitive characters by which they can be collectively separated from nauplii of other genera. This is due to the fact that penaeid nauplii are very simple forms having the same general shape and relatively few setae, all of which minimizes the possibility of distinctive, interspecific variation.

The following characters serve to distinguish *Sicyonia* protozoeae from those of other penaeid genera: The first antenna is relatively long, about 1½ times as long as the endopod of the second antenna, and bears three long terminal setae. The rostrum, when present, is very short with no supraorbital spines. The labrum does not possess a ventral spine, and the outer pair of caudal spines extends inwardly across the furcae.

The lack of dorsomedial spines on the first five abdominal segments is usually a sufficient criterion for identifying *Sicyonia* myses. Other useful characters are the presence of ventromedial spines on the first five abdominal segments, and the absence of hepatic spines on the carapace.

As pointed out by Heldt (1938), metamorphosis among the Penaeidae is very gradual with relatively minor differences separating most substages. Because distinction of successive substages can only be accomplished somewhat arbitrarily, different investigators examining the same kind of developmental material might easily have different opinions as to the number of substages represented. We believe this subjectively largely explains the variation in substage count recorded for *Sicylonia* larvae (Table 2). So, to facilitate comparison of the species described in Table 2, we have taken the liberty of placing the larvae of some authors in slightly different substage categories.

VI. Summary

Five nauplial, three protozoeal, four mysis, and the first postlarval stages of the rock shrimp, *Sicyonia brevirostris* Stimpson, reared from eggs spawned in the laboratory, are described and illustrated. Temperatures during rearing varied between 21.0° and 24.6° C. Salinity, which was 24.5‰ at the start, rose to a maximum of 27.4‰. The pH varied from 8.06 to 8.20. Under these conditions, the larvae developed to the first postlarval stage in 29 days.

S. brevirostris larvae are compared with corresponding substages of three previously described species of *Sicyonia.* It was noted that the larvae of all four species possess characteristics which serve to distinguish them from one another.

VII. Literature Cited

Anderson, W. W., and M. J. Lindner, 1943. A provisional key to the shrimps of the Family Penaeidae with especial reference to American forms. *Trans. Amer. Fish. Soc.,* 73: 284-319.

Cook, H. L., in press. A generic key to the protozoean, mysis, and postlarval stages of the littoral Penaeidae of the northwestern Gulf of Mexico. *Fish. Bull. U. S. Fish. Wildlife Serv.*

Gurney, Robert, 1943. The larval development of two Penaeid prawns from Bermuda of the genera *Sicyonia* and *Penacopsis. Proc. Zool. Soc. Lond., Ser. B.,* 113: 1-16.

Heldt, Jeanne H., 1938. La reproduction chez les Crustacés Décapodes de la famille des Pénéides. *Ann. Inst. Océanogr. Monaco,* 18: 31-206.

Lunz, G. Robert, 1945. Carolina shrimps of the genus *Eusicyonia.* The *Charleston Museum Leaflet No.* 20, 12 p., Charleston, S. C.

_____, 1957. Notes on rock shrimp *Sicyonia brevirostris* (Stimpson) from exploratory trawling off the South Carolina coast. *Contributions from Bears*

Bluff Laboratories, No. 25, 10 p., Wadmalaw Island, S. C.

Pearson, John C., 1939. The early life histories of some American Penaeidae, chiefly the commercial shrimp, *Penaeus setiferus* (Linn.). *Bull. U. S. Bureau Fish.*, 49(30): 1-73.

Pike, R. B., and D. S. Williamson, 1964. The larvae of some species of Pandalidae (Decapoda). *Crustaceana*, 6: 265-284.

October 11, 1965

FISHES TAKEN IN MONTHLY TRAWL SAMPLES OFFSHORE OF PINELLAS COUNTY, FLORIDA, WITH NEW ADDITIONS TO THE FISH FAUNA OF THE TAMPA BAY AREA

MARTIN A. MOE, JR.
and
GEORGE T. MARTIN,
Florida Board of Conservation Marine Laboratory
St. Petersburg, Florida

Abstract

Monthly collections of fishes were made at nine stations offshore of Pinellas County, Florida, from November, 1962, to June, 1963. Data on 2,317 fishes, representing 72 species, are reported. Occurrence of various species, relative abundance at certain depths and environmental descriptions are presented. Growth and other biological data are given for the 12 species most numerous in the catch. Salinity differences were not considered significant since the observed range between highest and lowest values was only 6‰. Complete temperature data with a generalized analysis are also presented. Distinctive differences in the fish fauna at depth ranges of 15 to 18 ft, 25 to 45 ft, and 75 to 105 ft are demonstrated. Fifteen of the species collected are new to the ichthyofauna of the Tampa Bay area. Another 27 species new to the area are included, although they were not taken during the study. The number of fish species reported from the Tampa Bay area is extended to 312.

Introduction

This account, with the exception of new additions to the Tampa Bay ichthyofauna, concerns the fishes taken during sampling for adult shrimp at established stations offshore of Pinellas County from November, 1962 through June, 1963. This restriction limits the majority of the species listed to the smaller, slow-moving bottom fishes.

Data on 2,274 fish taken from November, 1962, through June, 1963 and 43 fish taken prior to this period at the same stations are included in this account. This is a relatively small number, but it represents one of the most extensive systematic collections from offshore stations in the Gulf of Mexico.

Since our study extended for only eight months, seasonal patterns exhibited by the fishes on their offshore range are not completely disclosed. Sampling was conducted only at night and may have influenced the composition of the fish catch. Sampling was limited to one or two 15-minute trawls at each station using a 16-foot trynet (otter trawl). Obviously only a representation of the species present could be collected, thus these data are interpreted by species rather than by habitat. Effort at each station was not consistent because of inclement weather and unsuitable bottom for trawling. Some stations were trawled five times during the study and others were trawled up to 13 times. Except for one of the authors (Martin), the personnel and the vessel varied during the course of the study.

Certain factors limit the value of all systematic sampling programs of offshore biotopes. Most important is the extreme difficulty of repeatedly sampling exactly the same area. The problems of determining exact position at sea are well known and need no elaboration here. We are reasonably certain that all of our samples were taken

* Current address: Bears Bluff Laboratory, Wadmalaw Island, South Carolina.
Contribution No. 93

EDITORIAL COMMITTEE FOR THIS PAPER:

HARVEY R. BULLIS, JR., Base Director, Exploratory Fishing and Gear Research Base, U. S. Bureau of Commercial Fisheries, Pascagoula, Mississippi

GORDON GUNTER, Director, Gulf Coast Research Laboratory, Ocean Springs, Mississippi

VICTOR G. SPRINGER, Associate Curator, Division of Fishes, U. S. National Museum, Washington, D. C.

from the same general area at each station. Our certainty is based on compass headings, running time, approximate depth, and visual orientation points for most stations.

A primary work on the ecology of the Gulf fishes, conducted on the Texas coast, is by Gunter (1945). Many papers dealing with the biology of typical eastern Gulf of Mexico fishes of inshore, nearshore, or closely adjacent waters have appeared. The more extensive of these, in order of their geographic location from south to north, are: Longley and Hildebrand (1941) at the Tortugas Islands; Springer and McErlean (1962) at Matecumbe Key; Tabb and Manning (1961) at northern Florida Bay; Springer and Woodburn (1960) at Tampa Bay; Kilby (1955) at Cedar Keys and Bayport; Reid (1954) at Cedar Keys; Joseph and Yerger (1956) at Alligator Harbor; Miles (1951) at Apalachicola Bay; Bailey, Winn, and Smith (1954) at the Escambia River; Boschung (1957) at Mobile Bay; Gunter (1938) at Barataria Bay; and Darnell (1958) at Lake Pontchartrain. The locations of these studies are spaced over six degrees of north latitude and span approximately 1,000 linear miles of the Gulf of Mexico shoreline.

Systematic analyses of the fishes taken during commercial shrimping operations in various offshore areas for the Gulf are presented by Hildebrand (1954 and 1955) and the Florida Board of Conservation (1951). These studies, especially those of Hildebrand, provide invaluable data on commercially important areas by listing the species present and their relative abundance in the catch. Even though very little hydrographic, seasonal, or specific habitat data were included in those studies, these papers form the bulk of our ecological knowledge of the shore fishes in the eastern sector, and offshore areas generally, of the Gulf of Mexico.

Springer and Woodburn (1960) contributed significantly to our knowledge of the biology and ecological relationships of fishes in the Tampa Bay area. The present paper extends this knowledge into the offshore range of several species, thus complementing their extensive work.

Station Location and Description

Most stations are within the region affected by tidal flushing of Tampa Bay. Each station covered an area of one square mile and, with a few exceptions (primarily the stations farthest offshore), all samples were taken within this boundary.

Two generalized bottom types were encountered: a flat bottom of hard, fine sediments isolated from any reef formations, and a flat bottom of coarse lightweight sediments in the immediate vicinity of limestone base reefs. The limestone reef environment is, according to Springer and Woodburn (1960), "one of the least known biocoenoses in the Gulf of Mexico." Phillips and Springer (1960) reported on the algae typically found on these reefs and presented a physical description of the general reef configuration. Springer and Woodburn (1960) and Moe (1963) also discussed the offshore reef environment of this general area. These reefs were avoided as much as possible during our trawling, but as damaged nets testify, we were not always successful. Many of the fishes that appeared in our nets are common in the vicinity of these reefs: sparids, pomadasyids, sciaenids, and serranids. Small pieces of rocky reef, shell, and sponge were often taken in the nets also, thus we feel that we obtained many of the smaller fishes that dwell on or around the reef.

Stations 2, 3, 4, and 6 are the only stations that yielded fish each month of the eight-month period, and these stations are essentially the basis of our analyses. A total of 2,050 fishes, representing 90.1% of the fishes taken during the eight months, were trawled at the above stations. Stations 1, 7, 8, and 9 were not always fished and then only yielded fishes sporadically because of trawling difficulties. The production at these latter stations, 267 fishes collected in 14 successful trawl hauls, supplements the data from the four main stations. The stations are grouped according to the general depth range in which they occur to facilitate comparisons. Stations 1 and 7 are respectively the shallow and deep extremes of the 1, 4, 6, and 7 grouping. Stations 8 and 9, though not thoroughly sampled, indicate extensive changes in the fish fauna of the deeper waters.

Stations 1 through 9 are mapped in Figure 1 and the physical data for stations 1, 2, 3, 4, 6, 7, 8, and 9 are cumulatively presented in Table 1. Stations 4, 6, and 7 are in an area that is frequented by commercial shrimp harvesters.

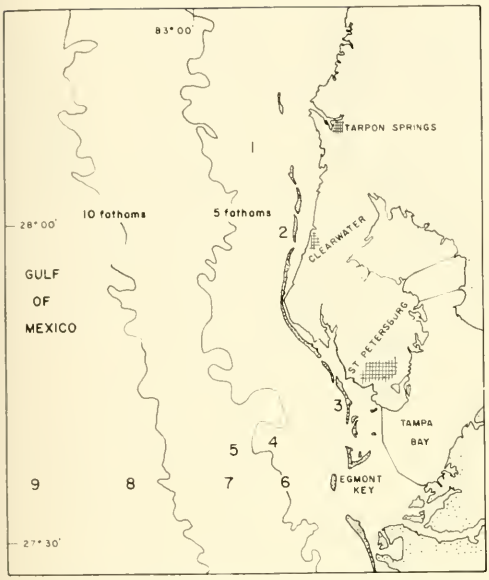


Figure 1. The Tampa Bay area and adjacent offshore waters. Numerals indicate the locations of stations 1 through 9.

STATION 1: 28°07′N 82°54′W

Station 1 is the northernmost station and is least affected by the discharge of Tampa Bay, although the discharge of the Anclote River creates the same general environmental conditions. This station is located about four miles from the Anclote Key lighthouse of an azimuth of 228°. Depths ranged from 18 to 30 feet, but almost all specimens collected were taken within a few feet of the mean depth of 23 feet.

Station 1 was trawled five times. Suitable bottom for trawling could not easily be found and this difficulty prevented consistent sampling. Trawls were generally made on a north-south axis whenever an area of flat bottom could be found. This station was especially destructive to our nets as they frequently caught on the bottom and were damaged. This was always the first station visited, thus our operations usually took place during the early hours of the night. Station 1 typifies the general bottom type of coarse lightweight sediments in the immediate vicinity of limestone reefs.

Station 1 was visually examined by the senior author with SCUBA gear to augment the fathometer recordings. These observations were made during daylight on November 19, 1963, on the northwest quadrant of the station. A flat bottom evenly covered with lightweight, coarse sediments mixed with a finer silt covered most of the area examined. This lightweight sediment layer (30 to 50 mm deep) could easily be disturbed and produced a dense cloud that settled in a matter of minutes. The sediments became more compact and finer grained as they extended downward. The sediment surface was investigated to a depth of about 165 mm. Many small pieces of shell and coral were recognizable, and these became more frequent and larger as the sediments graded into the rocky patch reef. There were one major and several minor patches of limestone rock reef in the area examined, a total of about 900 square yards of bottom. These rocky areas were 2 to 3 feet high and were very irregular with many cliffs, caves, and crevices. These reef areas were the center of almost all observed life. Attached invertebrates were profuse and formed much of the reef cover. Several large loggerhead sponges, *Spheciospongia (vesparia?)*, were observed. One was measured and was approximately four feet high and three feet across. Much of the general area offshore of Tarpon Springs has been described to a limited degree by Dawson and Smith (1953) and de Laubenfels (1953) in conjunction with surveys on sponge disease.

Many fish were observed during the dive, but few of these were taken during the sampling at night. Larger serranids, sparids, and pomadasyids were seen most frequently.

STATION 2: 27°58′30″N 82°51′W

This station is located due west of Clearwater Beach about one mile offshore of the surf line. The buoy lights of the ship channel to the south and prominent shore lights allowed rapid orientation during night sampling. Depths varied from 15 to 20 feet.

Sampling conditions were always excellent at this station, thus a relatively large number of trawl hauls was made. Trawl hauls were made parallel to the beach, and always yielded many small fishes.

Station 2 typifies the general bottom type of a flat surface of hard, fine sediments isolated from any reef formations. Visual examination was made by the senior author during daylight on November 19, 1963, and the following observations were recorded. The bottom was hard, flat, marked with low ripples, and consisted of homogeneous sedi-

TABLE 1

Data summary for all stations from November, 1962 to June, 1963. All tows were made with a trynet unless otherwise specified.

Station	Date	No. of Tows	Depth (Ft.)	Salinity ‰ Surface	Salinity ‰ Bottom	Temp. °C Surface	Temp. °C Bottom	No. of Fish Taken
1.	Nov. 14, 1962	1	24	34.4	34.4	17.8	17.8	5
	Dec. 19, 1962	1	23	33.4	33.8	13.3	12.4	17
	Jan. 15, 1963	1	18	34.5	34.8	15.1	15.1	5
	Feb. 23, 1963	2	22	31.2	33.4	14.6	14.3	14
	Mar. 18, 1963	0	25	32.1	32.8	23.2	22.0	0
	Apr. 17, 1963	0	26	35.0	34.7	21.2	21.2	0
	May 12, 1963	1 (dredge)	28	34.9	34.9	24.2	24.6	0
	June 4, 1963	1	24	36.7	36.3	27.7	27.9	0
	TOTALS	7						41
2.	Nov. 14, 1962	1	18	33.2	33.4	17.4	17.9	48
	Dec. 19, 1962	1	17	32.3	33.4	13.6	12.5	195
	Jan. 15, 1963	2	16	35.1	34.4	15.3	15.4	119
	Feb. 23, 1963	2	20	31.8	32.9	14.6	14.4	32
	Mar. 18, 1963	2	15	32.1	32.5	24.2	23.8	78
	Apr. 17, 1963	1	18	34.5	34.0	22.0	22.0	45
	May 13, 1963	1	18	34.9	35.5	25.0	24.6	39
	June 4, 1963	1	15	36.1	35.8	27.8	28.0	7
	June 7, 1963	1	15	36.0	35.7	—	—	78
	TOTALS	12						641
9.	Nov. 15, 1962	1	18	32.6	32.5	17.9	17.9	34
	Dec. 20, 1962	2	17	33.5	34.1	13.6	13.3	274
	Jan. 16, 1963	2	19	34.8	35.1	16.0	16.0	44
	Feb. 24, 1963	2	18	32.8	33.0	15.9	15.5	35
	Mar. 19, 1963	2	15	32.8	33.2	23.8	22.4	394
	Apr. 18, 1963	1	16	34.5	34.6	21.9	21.9	65
	May 13, 1963	1	12	35.6	36.2	25.0	23.7	17
	June 5, 1963	1	12	36.6	36.6	28.2	28.5	3
	June 6, 1963	1	15	36.1	36.6	28.3	28.5	61
	TOTALS	13						927
4.	Nov. 15, 1962	1	30	33.6	34.6	18.6	18.6	11
	Dec. 20, 1962	1	32	34.0	34.6	13.6	13.9	0
	Jan. 16, 1963	1	30	34.7	35.7	16.0	16.0	11
	Feb. 24, 1963	2	28	34.0	34.4	15.5	15.4	23
	Mar. 19, 1963	2	30	34.0	33.8	23.2	21.5	68
	Apr. 18, 1963	1	33	35.9	35.8	21.7	21.5	20
	May 13, 1963	1	30	36.8	37.0	24.6	22.0	5
	June 5, 1963	1	27	36.8	36.8	27.5	27.5	9
	June 6, 1963	1	27	36.1	36.0	27.9	27.0	27
	TOTALS	11						174
5.	Discontinued prior to 8 months study.							
6.	Nov. 15, 1962	1	30	33.1	35.5	18.4	18.4	10
	Dec. 20, 1962	2	30	33.4	34.7	14.5	14.6	105
	Jan. 16, 1963	2	29	35.5	36.0	16.2	17.0	44
	Feb. 24, 1963	1	32	33.5	33.3	15.8	16.4	24
	Mar. 19, 1963	1	30	34.8	34.3	23.9	23.8	28
	Apr. 18, 1963	1	30	36.8	35.7	21.2	21.0	26
	May 13, 1963	1	31	36.9	36.8	22.8	22.5	5
	June 6, 1963	1	27	36.3	36.3	28.0	27.7	23
	TOTALS	10						265

TABLE 1 (Continued)

Station	Date	No. of Tows	Depth (Ft.)	Salinity ‰ Surface	Salinity ‰ Bottom	Temp. °C Surface	Temp. °C Bottom	No. of Fish Taken
7.	Nov.	0						0
	Dec. 21, 1962	2	42	35.0	35.1	16.1	15.7	7
	Jan. 16, 1963	1	50	35.8	36.2	16.2	16.6	9
	Feb. 24, 1963	2	50	34.5	34.6	16.0	16.2	4
	Mar. 20, 1963	1	42	34.4	34.3	22.7	20.1	23
	Apr. 18, 1963	1	48	36.9	36.9	20.4	19.3	14
	May 13, 1963	1	44	36.2	36.4	21.2	23.3	0
	June 5, 1963	0						0
	TOTALS	8						57
8.	Nov.	0						0
	Dec.	0						0
	Jan. 17, 1963	1	70	36.8	36.3	17.4	17.3	3
	Feb. 25, 1963	1	84	35.4	35.7	16.4	16.6	4
	Mar. 20, 1963	1	72	34.8	34.7	22.4	18.3	0
	Apr.18, 1963	1	81	36.8	36.5	20.3	18.3	3
	May 14, 1963	1 (dredge)	81	35.8	36.4	23.5	21.0	0
	June 6, 1963	0						0
	TOTALS	5						10
9.	Nov.	0						0
	Dec.	0						0
	Jan.	0						0
	Feb. 25, 1963	1	102	35.7	35.8	17.2	17.6	9
	Mar. 20,, 1963	1	100	36.1	36.0	21.2	16.2	0
	Apr. 18, 1963	0	108	36.5	37.5	21.0	19.0	0
	May 14, 1963	1 (dredge)	108	35.8	36.9	23.2	22.0	0
	June 6, 1963	2	105	37.2	36.8	27.0	22.8	150
	TOTALS	5						159

Total number of fish taken from all nine stations..... 2274
Fish taken prior to November, 1962..... 43

TOTAL 2317

ment layers. The surface layer was very lightweight and consisted of a brown, organic, drifting material which was concentrated in shallow depressions and between the crests of the bottom ripples. The primary sediment layer consisted of sand and bits of shell and coral which produced a silty cloud when disturbed and appeared to be of the same composition as, but more finely grained than, the analogous sediments of the first station. This primary sediment layer was about 50 mm thick and gradually graded into compact gray clay infused with particles of shell. Approximately 600 sqaure yards were examined at the offshore edge of station 2. No fish were observed, but visibility was limited to about eight feet. The most abundant animal was an anemone, *Anemonia sargassensis*, which was attached to everything that offered a large enough base, including parchment worm tubes, shells, sticks and other organic debris.

STATION 3: 27°43'N 82°45'W

This station is located offshore of St. Petersburg Beach about one mile west of the surf line and offshore of the Don-Ce-Sar building. Depths ranged from 12 to 19 feet, although the extreme variations from the mean of 16 feet were usually not frequent.

This station was sampled most (thirteen 15-minute trawls, one more than station 2) and produced the greatest number of fishes. Trawling operations were conducted parallel to the beach, and depth was consistent during each haul. Trawling was always smooth and no rock or other irregularities were detected by the net or fathometer.

The topography of stations 2 and 3 are the same. These two stations represent the

same general habitat and are often grouped together in the analysis of data.

STATION 4: 27°39′N 82°52′W

This station is located about 2¾ miles due north of the entrance to the Egmont ship channel. Depths ranged from 27 to 33 feet and the mean depth was 30 feet. Little difficulty was experienced in finding and trawling this area.

This station had a bottom type intermediate to stations 1 and 2. Reef formations were present, but of such low relief that trawling was not hindered. Although visual examinations were not attempted, fathometer recordings and net production suggest that the general bottom configuration consisted of hard flat sediments with occasional low rocky reef areas and patches of shell.

STATION 5: 27°39′N 82°56′30″W

This station is located approximately 5 miles due west of station 4. It is most analogous to station 1, although it exhibits a greater extent of rugged limestone reef. Sampling was discontinued in June, 1962, because trawling was not feasible on the rugged bottom, and it is not part of our eight-month study. It is mentioned because it contributed a few specimens to our collection before being discontinued.

STATION 6: 27°34′45″N 82°51′W

This station is located approximately 0.2 miles due west of Buoy R-2, at the mouth of the Egmont Ship Channel, on an azimuth of 253° from the Egmont Key Lighthouse. Depths ranged from 27 to 32 feet with a mean of 30 feet. Difficulties were seldom encountered during trawling operations. This station is most analogous to station 4 in depth and bottom composition, although there seemed to be fewer and less extensive patches of low reef and shell. For our purposes, stations 4 and 6 represent the same general habitat.

STATION 7: 27°35′N 82°56′W

This station is located about 1 mile due west of the sea buoy of the Egmont Ship Channel. Sampling at this station began in December, 1962, and continued through April, 1963. May and June samples were not taken because of lack of suitable bottom for trawling. Depths ranged from 42 to 52 feet and the mean depth was 46 feet. Location was indefinite at these distant offshore stations since visual reference points were either vague or absent. Depth and running time due west of the sea buoy were the criteria for station identification. Gross error in locating station 7 was avoided since the sea buoy was nearby.

Operational difficulties similar to those at station 1 were encountered. Depth varied during trawling to a greater extent at this station than at the others. Bottom contours recorded on the fathometer included slopes and reef formations. The physical description of station 1 is generally applicable to station 7.

STATION 8: 27°35′N 83°07′W

This station is located about 20 miles due west of Egmont Key. Depth and running time from the Egmont channel sea buoy were the criteria for station location. This station was sampled once a month from January through May at depths ranging from 70 to 84 feet, and averaging 77.4 feet. The bottom type of station 8 appears similar to that of station 7.

STATION 9: 27°35′N 83°17′W

This station is located about 30 miles due west of Egmont Key. Depth and running time were also employed to locate this station each month. Samples were taken during four months. Depths ranged from 98 to 108 feet and averaged 100 feet. The bottom type is basically similar to stations 1, 5, 7, and 8.

Temperature and Salinity

Salinity differences between stations during this eight-month period were not great enough to be considered significant. Surface salinities ranged from 31.2 ‰ at station 1 in February to 37.2 ‰ at station 9 in June. Bottom salinities ranged from 32.8 ‰ at station 1 in March to 37.5 ‰ at station 9 in April. There was a difference of only 6.3 ‰ between the highest and lowest recorded salinity during the eight months of the study. The greatest range at any station, irrespective of surface or bottom reading, was 5.5 ‰ at station 1 and the smallest range was 1.8 ‰ at station 9. Salinity tended to gradually incrase from November to June and gradually increased and stabilized with depth.

Temperatures were generally lowest during December, ranging from 12.4°C to 16.1°C at stations 1 through 7. The highest

temperatures were taken in June and ranged from 27.6°C to 28.4°C at stations 1 through 6. The greatest range between surface and bottom (4.2°C) was recorded at station 9 during June in 105 feet of water. At the shallow and mid-depth groups, stations 2 and 3, and stations 1, 4, 6, and 7, average surface and bottom temperatures did not vary more than 1°C during any one month. Temperatures were lowest in December, January and February, and rose sharply about 8°C in March. After a small drop in April, they rose steadily through June. Data are incomplete for stations 8 and 9, but the same general pattern of temperature change was present for surface temperatures. Bottom temperatures for this depth group did not fluctuate as rapidly as the shallow groups and lagged noticeably behind the surface readings during the spring temperature rise. All readings were taken at night.

Methods and Materials

Trips were conducted on board chartered commercial fishing vessels. These vessels were all equipped with fathometers which were used in determining depth and finding trawlable areas. A 16-foot balloon trynet (otter trawl) was the basic gear used for the collection of shrimp and fish. Whiteleather (1948) stated that the balloon trawl is built to open high and full at the mouth allowing the net to take fish well off the bottom. Nets were constructed of tarred, number 15 Duracot twine tied at a 2-inch stretched mesh. The 3-foot cod end was constructed of 1-inch stretched mesh. The head rope or cork line included floats and measured 18 feet, and the foot rope or lead line measured 18½ feet. These were attached to 30 by 15 inch wooden otter doors.

Hildebrand (1954) mentions that the fishing effort of otter trawls, measured in units of time per tow, is vague because the fishing characteristics of these nets have not been analyzed. However, some recent articles of analytical nature are based on observations, measurements, and photographs of otter trawls in operation (Sand, 1959; de Boer, 1959; and Scharfe, 1959). It is still difficult to standardize otter trawl operations. Some variables that prevent units of time from being accepted as exact standards are, nonuniformity in rigging of the nets, variation in net shapes, differences in weights affixed to the foot rope, speed and other variables of the vessels, and sweep of the net both empty and full. We kept our nets as standard as possible during the study to allow a general comparison of effort on a unit of time basis. The foot rope was always weighted with chain rather than lead and whenever the net was changed due to loss or damage the same style of rigging was used. The net was always set on the surface off the stern and any fouling was cleared before the net was lowered. Evidences of proper operation were obtained through yields of large amounts of flora and fauna characteristic of the bottom habitat.

On three occasions a steel dredge, 37 inches long, 30 inches wide and 14 inches high with a ¾-inch expanded metal liner was used when the bottom was too rugged to effectively use the trynet. The dredge was productive only at station 9, before the beginning of our eight-month study. This dredge sample yielded seven species of reef dwellers that were not taken at any other station.

Temperatures were determined *in situ* with a Whitney Underwater Thermometer Model TC 10 (Whitney Underwater Instruments, Box 521, San Luis Obispo, California) and later in the study with an Electrodeless Induction Salinometer Model RS-5 (Industrial Instruments Inc., 89 Commerce Road, Cedar Grove, Essex County, New Jersey). Before use of the salinometer, salinities were determined with calibrated salinometer bulbs (G. M. Manufacturing Company, 12 East 12th Street, New York, New York) and the readings then corrected for temperature.

Specimens were preserved in 10% formalin. A representative sample of each species was retained after counting and usually after measurement when large amounts of certain species were taken in a single trawl. All fishes retained from these collections are deposited in the collection of the Florida Board of Conservation Marine Laboratory.

Fishes taken during the first 10 months of the offshore sampling program, when specimens were only casually collected for the laboratory's ichthyological reference collection, are also included in this account. These 43 fishes were taken with the same gear (15 by dredge and 28 by trynet) and at the same stations as those during the eight months of our study. Their inclusion supple-

TABLE 2

Fishes taken in offshore waters of Pinellas Co., Florida

Species	approximate depths 15′ to 18′ Stations 2	3	25′ to 45′ Stations 1	4	5	6	7	75′ to 105′ Stations 8	9	Total
Gymnura micrura	–	2	–	–	1	–	–	–	–	3
Harengula pensacolae	–	3	–	–	–	–	–	–	–	3
Synodus intermedius	–	–	1	1	–	2	2	2	1	9
Bagre marinus	1	–	–	–	–	–	–	–	–	1
Galeichthys felis	–	13	–	–	–	–	–	–	–	13
Urophycis floridanus	1	–	–	1	–	–	1	–	–	3
Centropristes melanus	5	2	2	–	–	2	–	–	–	11
Diplectrum formosum	3	2	1	8	–	11	4	–	5	34
Ephinephelus morio	1	–	1	–	–	–	–	–	–	2
Serranus subligarius	–	–	–	–	–	–	–	–	1***	1
Serranus pumilio	–	–	–	–	–	–	–	–	1***	1
*Lutjanus synagris**	4	4	–	–	–	1	–	–	–	9
Apogon alutus	–	–	1	–	–	–	–	–	1***	2
Apogon conklini	–	–	–	–	–	–	–	1	–	1
*Apogon pseudomaculatus**	–	–	–	–	–	–	–		1***	1
Eucinostomus gula	6	4	–	2	–	3	–	–	–	15
Haemulon plumieri	–	–	1	–	–	–	–	–	–	1
Orthopristis chrysopterus	186	123	9	12	–	22	23	1	–	376
Bairdiella chrysura	98	247	3	–	–	1	–	–	–	349
Cynoscion arenarius	–	3	–	–	–	1	–	–	–	4
Cynoscion nebulosus	–	–	1	–	–	–	–	–	–	1
Equetus lanceolatus	–	–	–	–	–	–	–	2	–	2
Leiostomus xanthurus	16	16	–	–	–	3	–	–	–	35
Menticirrhus americanus	12	51	–	–	–	7	–	–	–	70
Menticirrhus littoralis	2	1	–	–	–	–	–	–	–	3
Micropogon undulatus	–	–	–	–	–	2	–	–	–	2
Calamus arctifrons	–	–	3	–	–	–	–	1	–	4
Diplodus holbrooki	–	–	8	–	–	–	–	–	–	8
Lagodon rhomboides	198	322	8	13	–	47	2	–	–	590
Chaetodipterus faber	5	5	1	–	–	4	–	–	–	15
*Chromis enchrysurus**	–	–	–	–	–	–	–	–	3***	3
Ioglossus calliurus	–	–	–	–	–	–	–	1	–	1
Garmannia macrodon	–	–	–	–	–	–	–	–	1***	1
Scorpaena brasiliensis	2	–	1	–	–	1	1	2	–	7
*Scorpaena calcarata**	–	–	–	–	–	–	–	1	4	5
Bellator militaris	–	1	–	–	–	–	–	–	–	1
Prionotus pectoralis	–	3	–	1	–	1	–	–	1	6
*Prionotus roseus**	–	–	–	–	–	–	–	–	4	4
Prionotus scitulus latifrons	28	47	–	88	–	90	12	–	–	265
Prionotus tribulus crassiceps	9	15	1	–	–	2	–	1	–	28
Astroscopus y-graecum	–	–	–	1	–	–	–	–	–	1
Blennius marmoreus	–	–	–	–	–	–	–	–	2***	2
*Ophidion beani**	–	–	–	–	–	–	1	–	–	1
*Otophidion grayi**	–	–	–	–	–	–	1	–	–	1
Ophidion holbrooki	–	1	–	–	–	–	1	–	–	2
*Ophidion welshi**	1	3	–	–	–	–	2	–	–	6
*Lepophidium jeannae**	–	–	–	–	–	–	–	–	1	1
Peprilus alepidotus	2	7	–	–	–	–	–	–	–	9
*Ancylopsetta quadrocellatu**	4	1	–	–	–	–	–	–	–	5
Bothus ocellatuso	–	–	–	–	–	1	–	–	1	2
*Bothus ocellatus**	–	–	–	–	–	1	1	–	–	2
*Citharichthys macrops**	–	–	–	5	–	1	1	–	4	11
*Cyclopsetta fimbriata**	–	–	–	–	–	–	–	1	–	1

TABLE 2 (Continued)

	approximate depths 15′ to 18′ Stations		25′ to 45′ Stations					75′ to 105′ Stations		Total
	2	3	1	4	5	6	7	8	9	
Etropus crossotus atlanticus	11	14	–	19	–	21	–	–	–	65
*Etropus rimosus**	–	–	–	–	–	–	–	–	57	57
Paralichthys albigutta	8	–	–	–	–	1	3	–	–	12
*Syacium papillosum**	–	2	–	–	–	8	–	–	67	77
*Achirus lineatus**	–	1	–	–	–	–	–	–	–	1
*Symphurus diomedianus**	–	–	–	–	–	–	–	–	3	3
Symphurus plagiusa	33	28	1	20	–	26	2	3	–	113
Gobiesox strumosus	–	–	–	–	–	–	–	–	1***	1
Alutera schoepfi	–	2	–	–	–	–	–	–	–	2
Stephanolepis hispidus	1	–	–	–	–	–	–	–	4	5
Lactophrys quadricornis	2	3	3	–	–	1	–	–	–	9
Sphaeroides nephelus	1	–	–	–	–	–	–	–	–	1
Chilomycterus schoepfi	1	1	–	–	–	–	–	–	–	2
*Diodon holocanthus**	2	–	–	–	–	–	–	–	–	2
Opsanus pardus	–	–	1	–	–	1	–	–	–	2
Porichthys porosissimus	1	6	–	4	2	4	–	1	1	19
Antennarius ocellatus	–	–	–	–	–	1	–	–	3***	4
Ogcocephalus cubifrons	1	–	–	–	–	–	–	–	–	1
*Halieutichthys aculeatus**	–	–	–	–	–	–	–	–	7	7
TOTALS	645	933	47	175	3	266	57	17	174	2317**
EFFORT (Number of 15-minute trawls during 8-month survey period)	12	13	7	11	–	10	7	5	5	
NUMBER OF SPECIES:										
by depth divisions	39				41			30		
by station	30	30	18	13	2	27	15	12	23	

* Not reported from the Gulf of Mexico in the area of Tampa Bay by Springer and Woodburn (1960) during the period of their study, but recorded by them from Tampa Bay, Old Tampa Bay, or Boca Ciega Bay.
** Including 43 fishes taken prior to November, 1962.
*** Fishes taken by dredge June 5, 1962 (37.1 ‰, 21.8°C)

ments the species taken during that period, although their data do not contribute to our species analyses.

Measurments were made on a standard 1-meter fish measuring board, usually after the fishes had been in 10% formalin for several days. In instances when the catch was extensive, measurements were made aboard the collection vessel. Fork length (FL) was taken on fishes with forked tails and total length (TL) was taken on fishes with lunate or truncate tails. Standard length (SL) is given wherever possible to facilitate comparison with other studies, but it was not taken consistently since it was not considered an accurate field measurement on small fishes.

Tables and graphs are based on either TL or FL, although the approximate SL for each 3 mm grouping is also listed. These standard lengths were obtained from fishes that were retained and do not represent the entire number collected; thus they are considered approximate, but accurate enough for comparative purposes.

Systematic Account

Nomenclature and phyletic family listing follow the presentation of the American

Fisheries Society (Bailey *et al.*, 1960). Only bottom temperatures are mentioned in the text unless otherwise stated. Figure 2 identifies the various graph symbols used in Figures 3 through 5. The 12 species of fishes that were most numerous (89.4% of the total catch) are discussed individually, and Table 2 summarizes the data for all species.

Diplectrum formosum (Linnaeus), Sand Perch

This species, unlike *Centropristes melanus* which commonly dwells on the reef areas, is usually found on the sandy interstices between reef formations. We collected 34 individuals, 99 to 229 mm TL, distributed through every month and every station except station 8. The largest collection, five individuals, occurred in June at station 9. Stations 4 and 6 yielded 56% of our specimens of sand perch. The only evident distributional pattern in regard to month or station was the occurrence of the largest fish on the stations farthest offshore, 7 and 9. Our data agree with the findings of Longley and Hildebrand (1941), Reid (1954) and Hildebrand (1955) who reported *D. formosum* from deep, sandy bottoms. This species is usually evident in the catches of party boats and during SCUBA diving excursions.

Orthopristis chrysopterus (Linnaeus), Pigfish

This species was taken during every month and was the second most numerous fish, 376 individuals, in our total catch. Springer and Woodburn (1960) presented an extensive analysis of the occurrence of young pigfish in Tampa Bay during the course of their study. Our data (Figure 2) supplement theirs by extending the area of investigation into the offshore waters. The months of our largest collections were December through March. These months are the period of scarcity for species on the inshore grounds as both Springer and Woodburn *(op. cit.)* and Reid (1954) indicated. The size range of our November through January collections from stations 2 and 3 corresponds to the October through December collections of Reid *(op. cit.)* and Springer and Woodburn *(op. cit.)*. Our data indicate that these fish, which apparently move to offshore locations, remain offshore and undergo more rapid growth with the advent of warmer temperatures. The lowest temperature at which this species was taken was 12.5°C.

O. chrysopterus is common in the more northern and more saline coastal environments of the Gulf. As Springer and Woodburn mentioned, its abundance in shallower coastal waters decreases in southern Florida. Hildebrand (1955) commented that this species was common in 6 to 10 fathoms on the pink shrimp grounds in the Gulf of Campeche during February and July, and Tabb and Manning (1961) classified them as abundant in Joe Kemp-Conchie Channel during the cold winter of 1957-58. The pigfish may be more abundant offshore than inshore in the southern regions of the Gulf of Mexico.

Bairdiella chrysura (Lacepede), Silver perch

This species was the third most numerous, 349 individuals, in our total catch. With the exception of four large specimens taken in deep waters, all silver perch were collected from our shallowest depth range, stations 2 and 3. Station 3, the sampling area nearest to Tampa Bay, produced 71.8% of the total collected. *B. chrysura* was present in our collections during every month except May, but was poorly represented during April and February. Springer and Woodburn (1960) did not take this species in April and took only the very young during May; however, their gear was not effective for the larger fish. Spawning for this species probably takes place about that time as Springer and Woodburn (1960), Reid (1954) and Gunter (1963) took the first young of the year in May.

We assume that the paucity of specimens in our collections for April and May is due to a spawning migration to inshore waters. Springer and Woodburn (1960) concurred with Gunter (1945) that spawning takes place in the bays. Our June collection is indicative of a return to the Gulf after spawning. Four individuals from the June collection were examined; two were gravid females (160 and 173 mm TL) with well-developed ova, and two were males (153 and 156 mm TL) in gross appearance, although sperm were not observed. This indicates that spawning may continue into June in the Tampa Bay area. The length and time of the spawning season may vary with annual me-

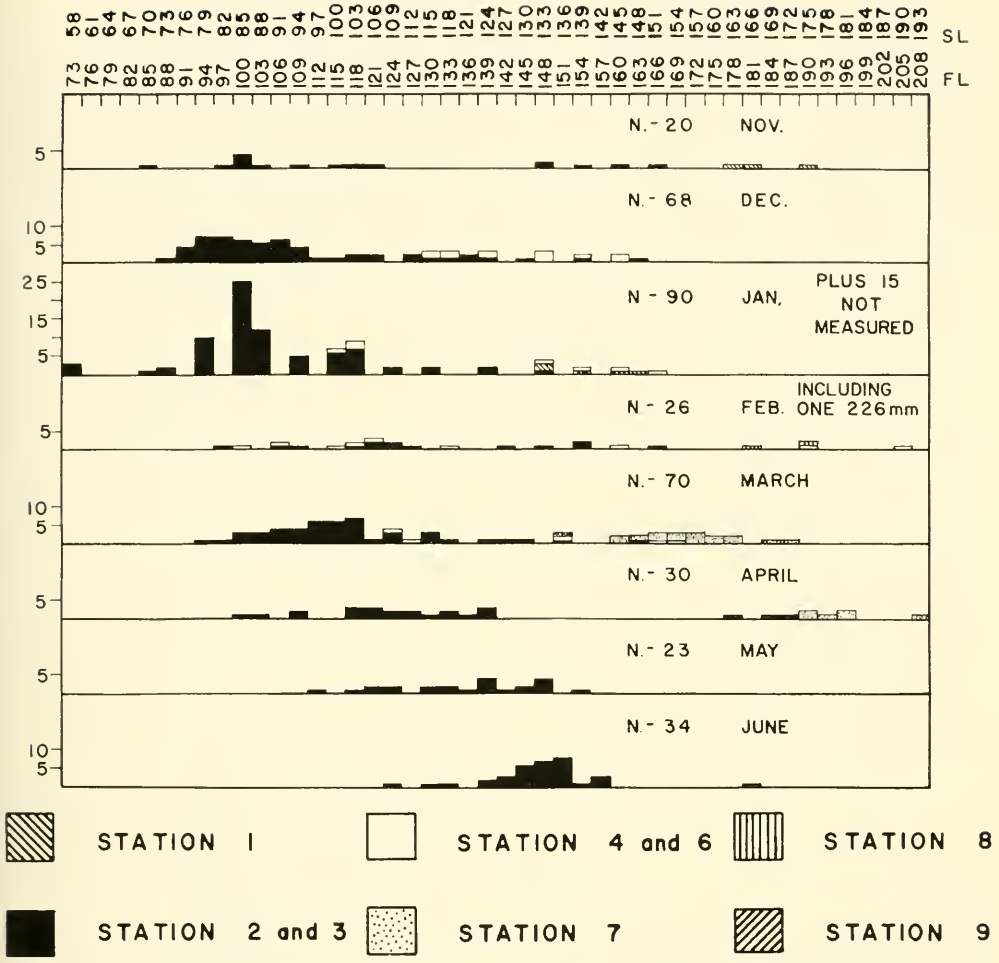


Figure 2. Monthly length-frequency dis- tributions of *Orthopristis chrysopterus*.

teorological conditions. Tabb and Manning (1961) collected running ripe silver perch during late February in the Florida Bay area, and Joseph and Yerger (1956) mentioned collecting young in June and September. Gunter (1945) reported that *B. chrysura* spawns during rising temperatures and moves into the open Gulf waters in fall and winter.

Our data (Figure 3) illustrate that the November and the large December collections approximate the size range of the specimens that both Springer and Woodburn (1960) and Reid (1954) took during those months. Growth in this first year class appears to speed up as the water warms. Gunter (1938) suggested that the life history of this species is short and implied that sexual maturity may be achieved during the first year. The normal life history probably spans only two annual cycles.

Leiostomus xanthurus (Lacepede), Spot

A total of 35 spot was collected from December through June. All of these, with the exception of three from station 6, were taken at stations 2 and 3. The collections for December and June represent 77.1% of total spot taken. Our specimens ranged in size from 125 to 205 mm TL. There were no tendencies toward monthly increments or regressions in size evident in our samples. *L. xanthurus* (particularly juveniles) is very abundant in coastal areas from Tampa Bay northward along the Gulf Coast. Bailey *et al* (1954) and Gunter (1963) recorded the

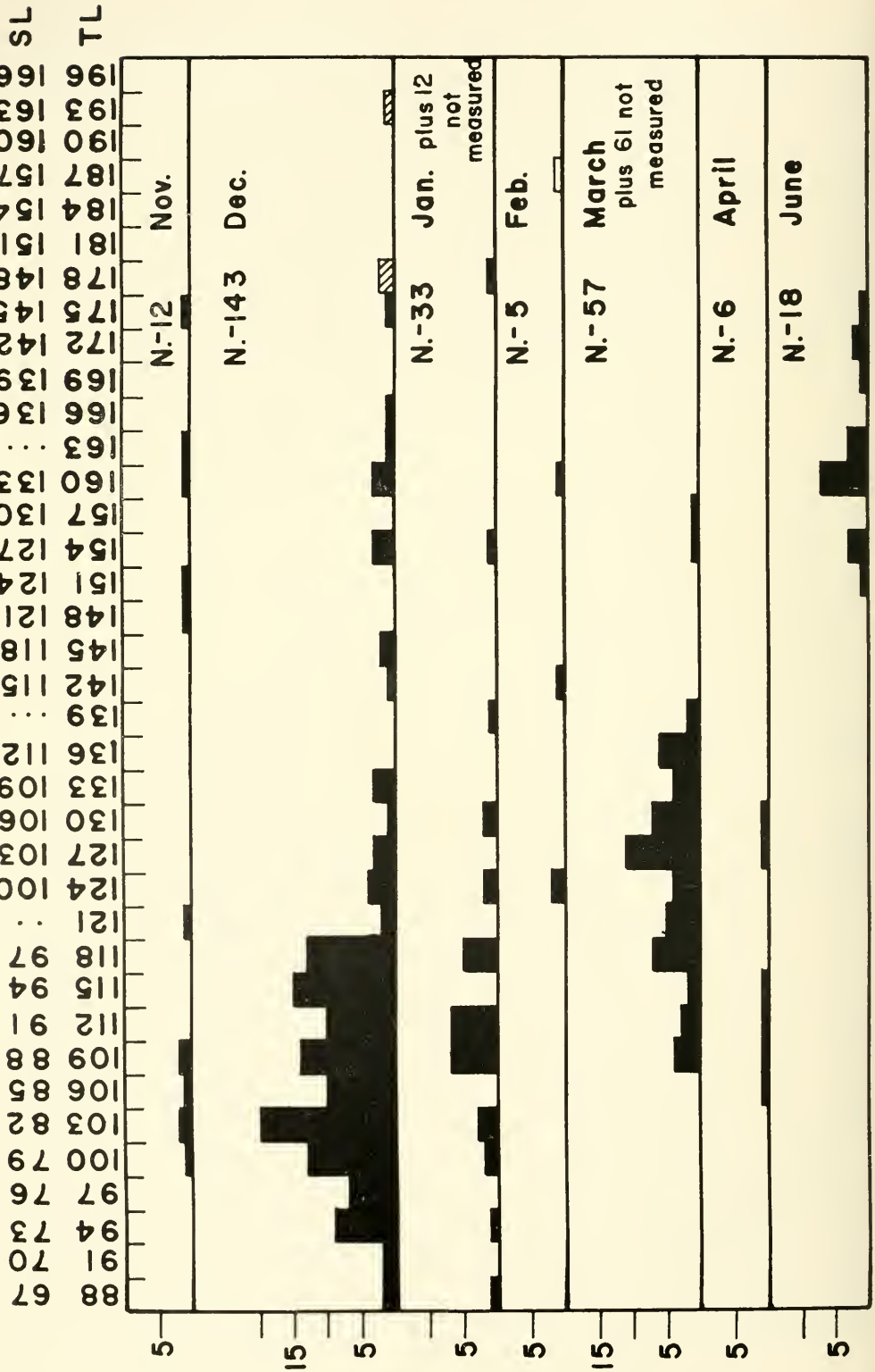


Figure 3. Monthly length-frequency distributions of *Bairdiella chrysoura*. Graph legend as in Figure 2.

young of this species from freshwater habitats, and Springer and Woodburn (1960), Kilby (1955), Joseph and Yerger (1956), and Miles (1951) all listed the spot as abundant in shallow waters. There is an apparent movement of young spot from inshore to offshore waters as they grow, and Springer and Woodburn *(op. cit.)* postulated a late winter spawning and an offshore migration in late summer for the Tampa Bay area. Spawning occurs primarily in December and January along the South Carolina coast with two and three-year-olds as the principle spawners (Dawson, 1958). Gunter (1938) suggested that the life cycle of the spot is short. Our findings of only a rather small, randomly sized population of adult fish in the offshore waters during and several months after the peak of spawning agree with the findings of the above authors.

Menticirrhus americanus (Linnaeus), Southern kingfish

This whiting was taken every month except November and May. Fifty-six percent of our 70 specimens were taken during December. All but seven individuals were collected at stations 2 and 3. Sizes ranged from 132 to 281 mm TL. The smallest fish was taken in January and the largest in April. As with the spot, no monthly size increments or regressions were evident. The gonads of specimens collected in February were examined, but were not ripe and sex was not distinguishable. One female (280 mm TL, station 2) was found among the four fish examined from the March collection. The other three (208 to 214 mm TL, station 3) appeared to be males. One female (216 mm TL) and one apparent male (214 mm TL) occurred in the April collection at station 3, and one female (186 mm TL) and an apparent male (191 mm TL) from station 2 comprised the June collection. All females had well-developed ova.

M. americanus is uncommon in waters of low salinity and according to Hildebrand (1954, 1955) and Miles (1951) it is the common whiting of the open Gulf. Our data indicate that the adults are commonest in the open Gulf during the winter and that spawning occurs from March to at least June. This agrees with Springer and Woodburn (1960) who suggested a May and June spawning at the time of their study, and Gunter (1945) who mentioned that this whiting leaves the bays in the winter.

Lagodon rhomboides (Linnaeus), Pinfish

The pinfish is one of the most abundant and characteristic fishes along the coastal region of the eastern and northeastern Gulf of Mexico. This species was taken during every month except November and, although it varied greatly in monthly abundance, it was the most numerous fish (590 individuals) in our total catch. Our data (Figure 4) will be discussed only where it adds to the findings of Caldwell (1957) and Springer and Woodburn (1960).

Pinfish first appeared in our collections in December. This December collection was the largest single collection of any species at any time during our study. The 261 individuals were taken at both the shallow and mid-depth stations with a strong pattern of size distribution according to depth evident. The size range of the smaller fishes (79 to 109 mm TL) from the shallower stations, 2 and 3, closely approximates the size ranges of the first year class collected by Springer and Woodburn (1960), Caldwell (1957) and to some extent Reid (1954). We believe this influx of pinfish at the shallower stations in December to be the migration of the first year class into the offshore waters as Caldwell postulated an offshore migration in cold weather, and Springer and Woodburn's first year class diminishes in average size and number inshore after December. The size range of the fishes from the mid-depth stations 1, 4, 6, and 7 indicates the presence of the second year class in the deeper waters. Spawning is thought to take place offshore in the Gulf during the winter months and our findings place Caldwell's first spawners, the second year class, in about 6 fathoms at this time. This second year class is no longer evident in our sampling after December, but few pinfish were taken in the following two months. We cannot adequately explain the sharp increase in numbers each third month of our study. No other species reflected this pattern of abundance. Growth apparently speeds up as the water warms since the size range of our June collection approaches those taken at the mid-depth stations in December. During the March collection, 149 pinfish were discarded from the catch at station 3 before

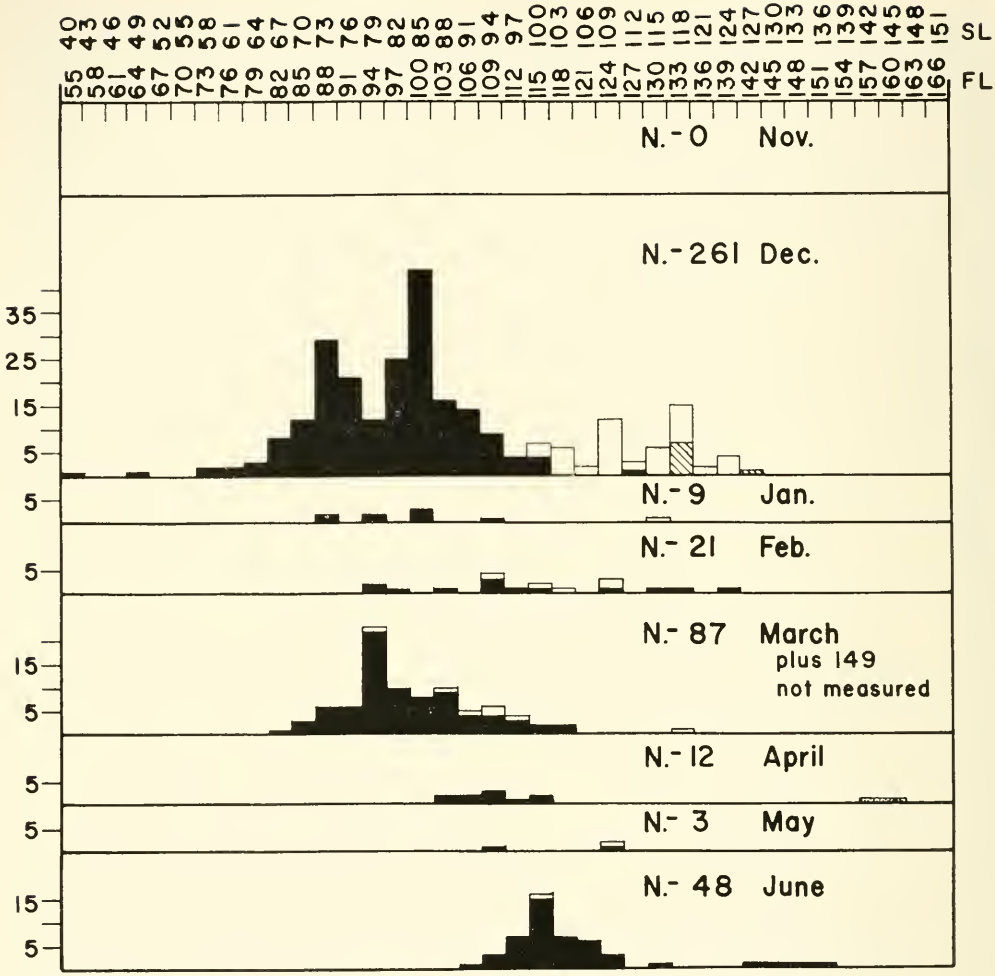


Figure 4. Monthly length-frequency distributions of *Lagodon rhomboides*. Graph legend as in Figure 2.

measurement. These fish were within the size range of the 87 that were measured.

Prionotus scitulus latifrons (Ginsburg), Leopard searobin

A total of 265 leopard searobins was collected. They were taken during every month with little variation in abundance. The largest collection occurred in March at the time of the strongest recruitment of young fish into our trawl catches. This subspecies is reported by Hildebrand (1955) as one of the most common and most characteristic fishes on the pink shrimp grounds off Campeche, and Springer and Bullis (1956) recorded this species from 14 stations in the Gulf. Our data (Figure 5) also indicate that this species strongly favors the offshore environment. Table 3 shows 69.7% of our specimens were collected at mid-depth stations. Springer and Woodburn (1960), Reid (1954) and Tabb and Manning (1961) did not take the leopard searobin in abundance during their studies, and the latter two papers report its occurrence adjacent to relatively deeper waters.

Our gear did not catch fishes smaller than 50 mm SL so the presence of fishes under this length would not be detected. Small individuals appeared in our trawls of the mid-depth stations during February and March and were present through June. Fish from the February through June collections were examined for sexual development and fe-

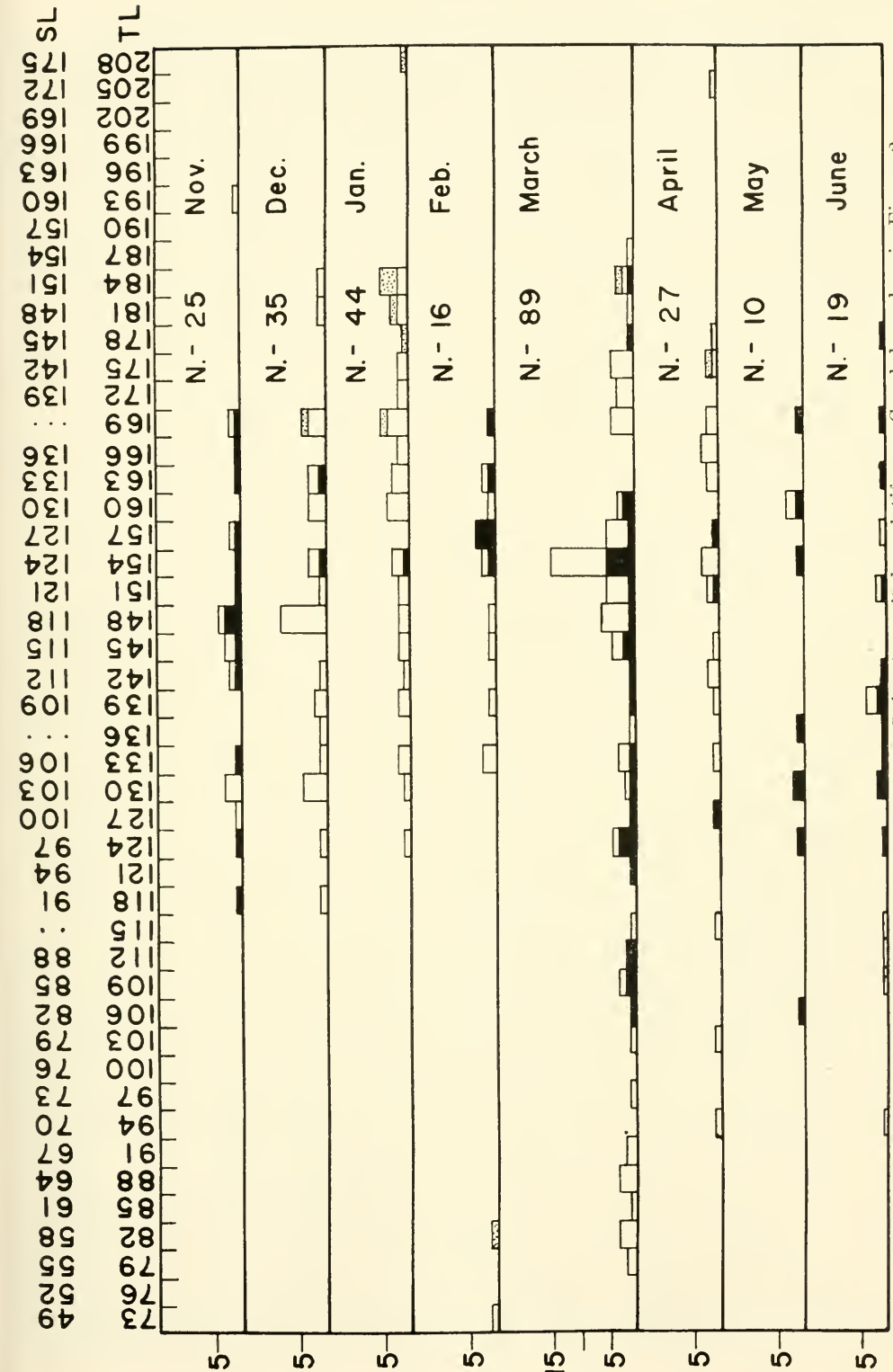


Figure 5. Monthly length-frequency distributions of *Prionotus scitulus latifrons*. Graph legend as in Figure 2.

TABLE 3
Percentages of fishes taken at each depth range for the 12 most numerous species in the catch

Species	Total Collected	depths 15′ - 18′ Percent	25′ - 45′ Percent	75′ - 105′ Percent
Bairdiella chrysura	349	98.9	.2	0
Leostomus xanthurus	35	91.4	8.6	0
Menticirrhus americanus	70	90.0	10.0	0
Lagodon rhomboides	590	88.1	11.9	0
Prionotus tribulus crassiseps	28	85.7	10.1	3.6
Orthopristis chrysopterus	376	82.2	17.5	.3
Symphurus plagiusa	113	54.0	43.4	2.7
Etropus crossotus atlanticus	65	38.5	61.5	0
Prionotus scitulus latifrons	265	28.3	71.7	0
Diplectrum formosum	34	14.7	70.6	14.7
Syacium papillosum	77	2.6	10.4	87.1
Etropus rimosus	57	0	0	100
Total number of fishes taken at all depths	2317	1578	548	191
Percentage of total number of fishes		68.1	23.7	8.2
Number of trawls producing fish	66	25	32	9
Percentage of the total effort		37.9	48.4	13.6

males with well-developed ova were observed in every month during this period. These females varied from 141 to 180 mm TL and were taken at both shallow and mid-depth ranges. The fish examined in February had well-developed ova; those fish examined from the March through May collections appeared to be nearing spawning condition; those examined from the June collection would extrude eggs upon pressure. Reid (1954) collected young fish (20 to 25 mm SL) in June, August, October, January, and May, a female in November with "slight ovarian development", and a male in December which "appeared to be near breeding condition." Springer and Woodburn (1960) collected small fish in every month except December, 1957 and August, 1958. The influx of small specimens in our mid-depth trawls of February and March, apparent breeding conditions of adults from December to at least June, and appearance of young fish at various times throughout the year indicate an extensive spawning season.

Prionotus tribulus crassiceps (Ginsburg), Bighead searobin

Twenty-eight bighead searobins were taken, 27 during the eight months of sampling and one (233 mm TL) at station 6 in March of 1962. Two additional large fish were taken, one 228 mm TL at station 6 in November and one 247 mm TL at station 8 in April. The remaining 25 specimens were collected at stations 2 and 3 every month from February through June. These fish ranged in size from 69 to 113 mm TL. A trend toward increasing size was noted for each monthly collection.

Several authors, Miles (1951), Joseph and Yerger (1954), and Tabb and Manning (1961) reported this species as commonly occurring at inshore locations, and Hildebrand (1955) considered it to be more abundant inshore than offshore. Our data, although limited, agree with this view since 85.7% of our specimens were taken at the shallowest stations.

Joseph and Yerger (1954) postulated a late summer and fall spawning and Gunter (1963) suggested a late fall and early winter spawning for *P. tribulus tribulus*. Hildebrand (1954) found a nearly ripe female on the Obregon shrimp grounds (Texas) in early August. Springer and Woodburn (1960) found young fish from October through February in the Tampa Bay area. We first found small individuals of *P. tribulus* at the same time of the appearance of small *P. scitulus*, February and March. These observations indicate that some spawning takes place in early fall, although spawning activity may extend over a greater period.

Etropus crossotus atlanticus (Parr), Fringed flounder

Fringed flounder were taken during every month for a total catch of 65 individuals. Total lengths ranged from 76 mm to 169 mm with the smallest fish taken in November and the largest in April. The June collection, 22 specimens, represented 33.8% of the total catch of this species. Ripe females were found every month from March through June and varied from 111 to 169 mm TL. The ovaries of fish from the June collection were turgid with eggs. Our data did not reveal any pattern of growth.

E. crossotus appears to be generally more common offshore than inshore. Hildebrand (1954, 1955) found it quite common in depths less than 17 fathoms offshore of Texas and Louisiana and on the Campeche Banks. Springer and Woodburn (1960) and Tabb and Manning collected very few, although it was common in the inshore collections of Reid (1954), Joseph and Yerger (1956), Miles (1951) and Gunter (1938). The center of abundance of this fish appears to move farther offshore in the more southern areas of the Gulf of Mexico. Reid (1954) found two young fish, 23 and 25 mm SL, in June and October, respectively, and postulated an "extended breeding season during spring and summer." Our data indicate that spawning takes place offshore from March until at least June, thus agreeing with Reid's findings.

Etropus rimosus, (Goode and Bean), Gray flounder

Fifty-seven gray founders were collected, all during June and only at station 9. Total length ranged from 101 to 133 mm and were arranged in two well-defined groupings which were probably composed of different sexes. All the fish (10 individuals) examined between 101 and 118 mm TL, were ripe females; and all fish (5 individuals) examined between 124 and 133 mm TL appeared to be male, although no milt was observed. No other species in our collections, except *Syacium papillosum*, displayed this sexual dimorphism of size. These data indicate an early summer spawning for this species.

E. rimosus is quite distinct from *E. crossotus* when comparative material is available. Our specimens agree with the description given by Longley and Hildebrand (1941). The snout of both sexes is covered with strongly ctenoid scales, and the pectoral fin on the ocular side is longer and larger than that of *E. crossotus* and has three to four horizontal, dark narrow bands which Longley and Hildebrand did not mention. The dark blotch on the lateral line just in advance of the dorsal and anal fin terminations varies from dark and well-defined to rather obscure. *E. rimosus* has three dark blotches equally spaced along the lateral line, although the posterior blotch, about the size of the eye, is largest and most distinct. The scales of *E. rimosus* are strongly ctenoid on the ocular side and mildly ctenoid on the blind side, whereas scales of *E. crossotus* are mildly ctenoid on the ocular side and smooth on the blind side.

Springer and Bullis (1956) and Hildebrand (1955) did not encounter this species, but Joseph and Yerger (1956) recorded it offshore of Alligator Harbor, and Briggs (1958) reported it from the southern Atlantic coast and the northeastern Gulf of Mexico. Evidently, *E. rimosus* is fairly uncommon and restricted to the offshore waters of the eastern Gulf.

Syacium papillosum (Linnaeus), Dusky flounder

Seventy-seven specimens were collected, and only 10 of these came from stations inshore of station 9. *S. papillosum* was taken in every month except March and May. The largest collection of 59 individuals came from station 9 in June, and the smallest and largest fish (76 and 229 mm TL) were included in this sample. About half of this collection was examined for sexual development, and 14 ripe fish were found. The eight females were mildly distended with roe and varied from 137 to 175 mm TL. The six males strongly exhibited the sexual dimorphic traits characteristic of the males of this species, *i.e.*, a cinereous blind side, two parallel blue lines between the right eye and the snout area, and long filamentous extensions on the dorsal rays of the pectoral fin of the ocular side. Several smaller males with their external sexual characters not fully developed were also included in the collection. These data indicate an early summer spawning, although activity may take place over an extended period. No growth data were available through our collections. Longley and Hildebrand (1941), Hildebrand

(1955), and Joseph and Yerger (1956) all reported *S. papillosum* from the offshore waters, and Springer and Bullis (1956) reported it from 36 *Oregon* stations in the Gulf of Mexico.

Symphurus plagiusa (Linnaeus), Blackcheek tonguefish

The blackcheek tonguefish was present every month, although it was rather scarce from December through February. A total of 113 specimens was taken from stations 1 through 8, but 54.0% came from the shallowest stations. Ginsburg (1951) considers it an inshore species since it ranges to only 14 fathoms. Our gear was selective for the larger individuals since most of the fish taken (124 to 174 mm TL) were wedged in the mesh of the net. Ripe females were found in the March through June collections and varied from 145 to 168 mm TL. Spawning appeared to occur in June; some of the females examined from that month had flaccid ovaries with many free eggs.

S. plagiusa is common in the offshore waters in many areas of the Gulf (Hildebrand, 1954, 1955; Gunter, 1945; Miles, 1951; and Joseph and Yerger, 1956) and the young are also occasionally taken in salinities below 7 ‰ (Springer and Woodburn, 1960; Gunter, 1963). Hildebrand and Cable (1930) postulated a May through October spawning period based on the appearance of juveniles off North Carolina. We agree with this concept of an extended spawning period since Gunter (1945) took a ripe female in April; Joseph and Yerger (1956) found young fish in July; Tabb and Manning (1961) reported taking small specimens of 20 mm (total length, we presume) in March and September; Springer and Woodburn (1960) and Gunter (1963) reported their smallest tonguefish, 19 mm SL and 29 mm TL respectively, in October; and Springer and McErlean (1962) found 26 and 21 mm SL tonguefish in January and February respectively.

Table 2 is both a summary and analysis of each species present in our collections. We do not feel the need to comment on each species taken since the sparsity of our data in most cases would allow only occurrence to be mentioned. The stations are arranged by depth, shallowest to deepest. A summary of the effort expended and the number of species taken at each station and depth range is included at the end of the table. The 43 fishes taken prior to the eight months of the study are included in this table, and since they represent only 1.9% of the total fishes taken, they are not distinguished unless they were part of a dredge collection. Springer and Woodburn (1960) discussed distribution and relative abundance of the species they observed in the Tampa Bay area. In Table 2, we have distinguished the species collected during our study that were not reported from the Gulf of Mexico by Springer and Woodburn (1960) in their Tables 20 or 22. Some of these fish were reported from the bay environs, but not the Gulf.

Only three specimens of *Urophycis floridanus* were taken, two in February at station 2 (92 mm SL) and at station 7 (114 mm SL) and one in March at station 4 (92 mm SL). According to Gunter (1945), Reid (1954) and Springer and Woodburn (1960), this species is found on the inshore areas during January through April. These individuals are generally juveniles as were our specimens.

Eight specimens of *Lutjanus synagris* (65 to 110 mm SL) were taken during November, three at station 2, four at station 3, and one at station 6. Another individual taken on September 13, 1962 (87 mm SL, 34.6 ‰, 30.6°C) at station 2 augments our collection to nine fish. Large individuals of this species are occasionally taken by party boats fishing the deeper waters during the summer, and Hildebrand (1955) reported *L. synagris* to occur frequently on the Campeche Banks between 6 and 16 fathoms. Juveniles appear to move inshore during the fall of the year. Reid (1954), Springer and Woodburn (1960) and Tabb and Manning (1961) found *L. synagris* to be either present or abundant only during September to December.

Menticirrhus littoralis was collected only three times during our study. Two specimens, 160 and 165 mm TL, were taken in November at station 2, and one near-ripe female, 260 mm TL, was taken at station 3 in March. Springer and Woodburn (1960) found this species abundant in the summer at their beach station only one mile distant from our collection site. These fish, in their larger size ranges up to 169 mm SL, would have been more frequent in our trawls if they were present at the nearshore stations.

Springer and Woodburn's data indicate a spring spawning, probably May, and our data corroborate theirs. The winter habitat of *M. littoralis* remains unknown.

One specimen of *Bellator militaris,* 56 mm TL, was taken at station 3 in June. It was evidently a stray from deeper waters since this species is common in collections from 100 fathoms offshore of the lower west coast of Florida.

Two species of *Bothus* were taken, *B. ocellatus* and one recently recognized, but not named, which was identified by Dr. C. R. Robins. These fish were taken at both mid-depth and deep stations. Springer and McErlean (1962) probably took both species at their shallow water station in the Florida Keys, and Tabb and Manning (1961) did not record these species from the more inshore area of Florida Bay. Hildebrand (1955) reported *B. ocellatus* as the commonest flatfish on the Campeche Bank in 6 to 10 fathoms in February, and common in 13 to 16 fathoms in July.

Citharichthys macrops was reported as very common on the Campeche Bank by Hildebrand (1955), but Longley and Hildebrand (1941) only reported two specimens. This species was not rare at our mid-depth and deep stations. Two ripe females, 144 and 205 mm TL, were taken in March at stations 7 and 9. Spawning probably takes place in the spring.

One specimen of *Gobiesox strumosus,* 65 mm TL, was taken in a dredge sample at station 9 on June 5, 1962 (37.1 ‰, 21.8°C). The collection of this individual offers a contrast to Springer and Woodburn's (1960) statement that this species is "strictly an inshore shallow water form." *G. strumosus* was also reported from the Gulf by Springer and Bullis (1956) who recorded it at 16 and 25 fathoms.

One large specimen of *Ogcocephalus cubifrons,* 267 mm TL, was taken at station 2 in June. Our identification is based on a similarity with the *O. cubifrons* of Longley and Hildebrand (1941) and the opinion of Springer and Woodburn (1960) that the common species of the Tampa Bay area is this form.

Dr. C. R. Robins kindly identified the Ophidiidae, *Bothus,* and *Chromis enchrysurus;* and Dr. Ernest Lachner graciously identified the Apogonidae for us. All other identifications are the responsibility of one of us (Moe).

Depth Relationships

It was not possible to ascertain the exact habitat from which each species was taken since our nets moved over a variety of bottom types and probably sampled several different biotopes during each haul. As a result, our analysis is restricted to the depth relationships of the 12 most numerous fishes in the total catch. Table 3 lists these fishes in order of their relative abundance at the shallowest stations. The depth preferences of these fish, within the limits of this study, are evident in Table 3.

The shallowest stations 2 and 3, produced the greatest number of fishes (68.1% of the total catch), although only 37.9% of the effective effort (trawls that took fish) was expended at these stations. The mid-depth stations received 48.4% of the effective effort and produced only 23.7% of the total catch. Our deep range, stations 8 and 9, was better balanced with 13.6% of the effective effort producing 8.2% of the total catch. The mid-depth stations had their own characteristic fishes and also exhibited fringe populations of typical inshore and offshore species. Although the analysis is very general, it demonstrates the distinctness of the bottom fishes at various depths offshore of Pinellas County.

Gunter (1945, 1950 and 1961) showed that salinity can be correlated with size in marine fishes, although a direct relationship may not exist. Larger fish are generally found in higher saline waters, and consequently are found deeper and farther offshore than smaller fish. Our data consistently exhibit the larger fish of most species occurring at the deeper stations. The salinity differential was probably too small to be significant in this distributional pattern. Depth then becomes one of the most obvious variables with a direct correlation to increasing size.

Appendix

During the course of this study, 15 species of fish were taken that have not been reported from the Tampa Bay area. An additional 27 species new to the area were taken in incidental collections since the publication of the above papers, and these records are also listed here. Springer and Wood-

burn (1960) and Springer (1961) recorded 271 species of fishes from the waters of the Tampa Bay area. The number of species of fishes now known from the Tampa Bay area is 312. The specimens on which the following records are based are deposited in the laboratory reference collection unless noted otherwise.

Carcharodon carcharias (Linnaeus). On February 10, 1965, a female white shark 11 ft. 10 in. total length was taken by the collecting crew of the Aquatarium with a 12 in. stretched mesh porpoise net. The capture occurred in four feet of water on a sand bar just offshore of Bunce's Pass at the north end of Mullet Key. The animal was photographed and discarded. There are two unconfirmed reports of white shark taken in the Tampa Bay area during the previous year.

Carcharinus obscurus (LeSueur). Springer (1961) reported two large specimens of *Eulamia (Carcharinus) floridana* stranded on a sand bar in Boca Ciega Bay on December 24 and 25, 1960. Garrick, *et. al.* (1964) demonstrated that these specimens were incorrectly identified and are actually *C. obscurus,* not previously reported from the Tampa Bay area by that name. *Carcharinus falciformis (C. floridana)* has not been taken in the Tampa Bay area.

Raja eglanteria Bosc. Two males, 490 and 540 mm TL, were taken with hook and line about 10 miles offshore of Clearwater Beach on February 2, 1963. Depth was 50 feet and bottom salinity and temperature were 33.8 ‰ and 14.9°C. Since that time, three other specimens of the clearnose skate, two females and a male, have been taken from offshore waters in the Tampa Bay area.

Raja texana Chandler. One female, 378 mm TL, was taken in a large trawl from the R/V *Hernan Cortez* on December 21, 1964, at approximately 27°23′N, 83°20′W in 120 ft. of water. This specimen was taken in the same trawl haul as *Bregmaceros atlanticus.* Although the location is just suoth of the defined Tampa Bay area, these records are considered applicable since both species have been reported north and south of this region (Springer and Bullis, 1956).

Sardinella brasiliensis (Steindachner). One individual, 179 mm SL, was found in a box of frozen bait obtained from the Pinellas Seafood Company. The fish was captured in a commercial shrimp trawl in March of 1964 about 8 miles offshore of Pass-a-Grille, Florida.

Saurida brasiliensis Norman. Two specimens, 51 and 52 mm SL, were taken in 80 ft. of water due west of Egmont Key on December 17, 1964. They were obtained in a dredge sample of the R/V *Hernan Cortez.*

Saurida normani Longley. One specimen, 273 mm SL, was taken in 20 fathoms at 27°52′N, 83°37′W on April 30, 1965. It was captured with a 40-foot fish trawl during operations of the R/V *Hernan Cortez.*

Trachinocephalus myops (Forster). This species is common in the offshore areas of Pinellas County, but not nearly as abundant as associated species of *Synodus.* Our record is based on a specimen, 162 mm SL, taken by the R/V *Hernan Cortez* with a trynet on December 17, 1964, in 80 ft. of water due west of Egmont Key.

Ophichthus ocellatus (LeSuer.) One specimen, 359 mm TL, was taken by Tom Stokel, a commercial bait shrimper, on January 23, 1964 on the south bank of Bunce's Pass channel in the vicinity of the Sunshine Skyway. It was captured in a frame trawl at about 2:00 A.M.

Bregmaceros atlanticus Goode and Bean. One specimen, 42 mm SL, was collected in a trawl haul on December 21, 1964, at 27° 23′N, 83°20′W in 120 ft. of water. Temperature was 20.3°C (bottom).

Holocentrus bullisi Woods. One individual, 123 mm SL, was taken on hook and line in 24 fathoms at 27°28′N on August 15, 1963 by a commercial grouper fisherman.

Rypticus arenatus Cuvier. Two specimens, 61 and 82 mm SL, were taken in 26 fathoms at 27°30′N, 83°48′W on May 24, 1965. They were captured in a 40-foot fish trawl during operations of the R/V *Hernan Cortez.*

Serranus phoeby Poey. One individual was collected in 32 fathoms at 27°31′N, 84° 01′W on May 24, 1965. It was taken with a 40-foot fish trawl during operations of the R/V *Hernan Cortez.*

Pseudopriacanthus altus (Gill). One specimen, 67 mm SL, was taken in a wire fish trap at 27°56′N, 83°81′W on March 30, 1965 during operations of the R/V *Hernan Cortez.* Depth was 18 fathoms.

Apogon pseudomaculatus Longley. One individual, 52 mm SL, was taken at station 9 on June 5, 1962.

Decapterus punctatus (Agassiz). Seven specimens (128 to 138 mm SL) were taken in a purse seine about 8 miles offshore of Clearwater Beach on June 17, 1964. Depth was 42 feet and surface salinity and temperature were 35.6 ‰ and 29.8°C.

Mullus auratus Jordan and Gilbert. Three individuals, 90 to 96 mm SL, were taken at 28°05′N, 83°25′W in a commercial shrimp trawl on June 20, 1964. The haul was made at night at a depth of 80 feet. Surface salinity and temperature were 35.6 ‰ and 30°C.

Pagrus sedecim Ginsburg. One specimen, 317 mm SL, was taken by hook and line on May 23, 1963 about 65 miles offshore of Egmont Key. It was caught on a rocky bottom at about 25 fathoms.

Bellator militaris (Goode and Bean). One individual, 42 mm SL, was taken at station 3 in the June collection.

Prionotus ophryas Jordan and Swain. One specimen, 104 mm SL, was taken in 18 fathoms at 27°46′N, 83°35′W on May 23, 1965, with a 40-foot fish trawl during operations of the R/V *Hernan Cortez.*

Prionotus pectoralis Nichols and Breder. One specimen, 81 mm SL, was taken in the March collection at station 4.

Opisthognathus lonchurus Jordan and Gilbert. One specimen, 105 mm SL, was found in the spewings of a large red grouper taken in 25 fathoms at 27°42′N on May 23, 1963. The jawfish is in excellent condition and had evidently been ingested only a short while before the capture of the red grouper.

Kathetostoma albigutta (Bean). Three specimens, 70, 100, and 239 mm SL, were taken in the same trawl haul as the previously listed *Rypticus arenatus* and the same data apply to this record.

Dactyloscopus tridigitatus Gill. One specimen was taken in a frame trawl by Tom Stokel on March 16 ,1965 in 4 ft. of water on the bay side of Egmont Key. A stand of *Thalassia testudinum* covered the sandy bottom.

Paraclinus fasciatus (Steindachner). One specimen, 39 mm SL, was collected in a dip net at the surface near the St. Petersburg Municipal Pier on May 31, 1963 by Tom Stokel. The Municipal Pier is located on Tampa Bay at about 27°46′N. Depth varies from 20 to 25 ft.

Blennius nicholsi Tavolga. One individual, 27 mm SL, was taken by W. K. Porter from near the dock on his property, 8430 Gulf Boulevard, St. Petersburg Beach, in August of 1963.

Ophidion welshi (Nichols and Breder). Two individuals, 252 and 265 mm TL, were taken in December at station 7. Four other specimens of *O. welshi* were subsequently taken at stations 2 and 3.

Ophidion beani Jordan and Gilbert. One specimen was taken at station 7 in the March collection.

Otophidium grayi Fowler. One specimen, 200 mm TL, was taken at station 7 in the March collection.

Lepophidium jeannae Fowler. One individual, 287 mm TL, was taken in the February collection at station 9.

Psenes regulus Poey. Two specimens, 121 and 116 mm SL, were taken in 92 ft. of water due west of Egmont Key on December 16, 1964. They were collected with a large mid-water trawl operated from the R/V *Hernan Cortez.*

Bothus sp. (unnamed). Two specimens were taken during our study. One, 92 mm SL, was taken in January at station 6; and one, 80 mm SL, was taken at station 7 in April.

Bothus ocellatus (Agassiz). Two specimens were taken during our study. One, 51 mm SL, was taken at station 6 in December; and one, 97 mm SL, was taken at station 9 in June.

Cyclopsetta fimbriata (Goode and Bean). One individual, 216 mm SL, was taken at station 8 in February.

Etropus rimosus Goode and Bean. This species is discussed in the text of this paper.

Syacium papillosum (Linnaeus). This species is also discussed in the text of this paper.

Symphurus diomedianus (Goode and Bean). Three individuals, 153 to 154 mm SL, were taken in the June collection at station 9.

Symphurus minor Ginsburg. One specimen, 45 mm SL, was taken in 80 ft. of water due west of Egmont Key on December 17, 1964. It was collected in a dredge sample from the R/V *Hernan Cortez.*

Symphurus urospilus Ginsburg. One specimen, 160 mm TL, was taken in the same haul as the previously listed *Mullus auratus* and the same data apply to this fish.

Alutera heudelotii Hollard. Three individuals, 174, 187 and 195 mm SL, were taken in 22 fathoms at 27°37′N, 83°43′W on May 23, 1965 with a 40-foot fish trawl during operations of R/V *Hernan Cortez*.

Lactophrys triqueter (Linnaeus). One specimen, 36 mm TL, was taken in a frame trawl on February 9, 1965 by Mr. Tom Stokel in 4 ft. of water on the Bay side of Egmont Key.

Halieutichthys aculeatus (Mitchill). Seven specimens were taken at station 9 in the June collection. One individual measured 80 mm TL and 49 mm disk width. All fish were about the same size.

Summary

1. From November, 1962 to June, 1963 fishes taken during a study of adult pink shrimp offshore of Pinellas County, Florida, were retained for monthly biological analysis. These fishes were taken by a 16-foot trynet at monthly intervals from nine stations. Gear was selective for the smaller, slow-moving bottom fishes. Few very young or relatively large fish were taken.

2. The stations have been grouped in general depth ranges. These are: stations 2 and 3, shallow, 15 to 18 feet; stations 1, 4, 6, and 7, mid-depth, 25 to 45 feet; and stations 8 and 9, deep, 75 to 105 feet. Station 5 was discontinued before the detailed analysis of fishes was begun. Stations 2, 3, 4, and 6 produced 90.1 percent of the total catch. Data from the other stations are supplementary to these basic collections.

3. A total of 2,317 fishes representing 34 families and 72 species was collected at these stations. Twelve species composed 89.4 percent of the total catch and are discussed in detail. The occurrence of the other species is presented in tabular form.

4. A difference of only 6 ‰ between the highest and lowest salinity reading was recorded during our study; thus, salinity is not considered a significant factor. Temperatures ranged from 12.4°C in December to 28.4°C in June.

5. The largest individuals of each species were generally found at the deeper stations.

6. The depth relationships of the 12 species most numerous in the catch are analyzed. Definite depth preferences were found in most species within the depth range of the study, 3 to 18 fathoms.

7. Fifteen of the 72 species taken had not previously been reported from the Tampa Bay area. These 15 species, along with 27 other species taken in incidental collections, are listed with data as new additions to the ichthyofauna of the Tampa Bay area. A total of 312 species of fish are now reported from this area.

Acknowledgments

It is our pleasure to acknowledge the following individuals for their contributions toward the completion of this paper. Mr. Vernon Senterfitt aided in the field work and in compilation of data and Mr. Phillip Heemstra assisted with the sorting and identification of specimens. Doctors C. Richard Robins, Donald P. deSylva, and Victor G. Springer graciously reviewed the manuscript and offered valuable criticisms and suggestions toward improvement. Mr. Robert M. Ingle, Director of Research of the Salt Water Fisheries Division of the Florida Board of Conservation critically reviewed the manuscript and offered encouragement throughout the study.

Literature Cited

Bailey, R. M., E. A. Lachner, C. C. Lindsay, C. R. Robins, P. M. Roedel, W. B. Scott, and L. P. Woods. 1960. A list of common and scientific names of fishes from the United States and Canada. *Amer. Fish Soc. Comm. on Names of Fishes*, Spec. Publ. No. 2: 1-102.

Bailey, R. M., H. E. Winn, and C. L. Smith. 1954. Fishes from the Escambia River, Alabama and Florida, with ecologic and taxonomic notes. *Proc. Acad. Nat. Sci. Philad.*, **106**: 109-164.

Boer, P. A. de. 1959. Trawl gear measurements obtained by underwater instruments. pp. 225-233. in: Hilmar Kristjonsson, ed. *Modern Fishing Gear of the World*. Fishing News (Books) Ltd., London.

Boshung, H. T. 1957. The fishes of Mobile Bay on the Gulf Coast of Alabama. *Ph.D Thesis, Univ. of Alabama*, v + 626, 1 pl.

Briggs, J. C. 1958. A list of Florida fishes and their distribution. *Bull. Fla. State Mus.*, **2**(8) 223-318.

Caldwell, D. K. 1957. The biology and systematics of the pinfish, *Lagodon rhomboides* (Linnaeus). *Bull. Fla. State Mus.*, **2**(6) 77-173.

Darnell, R. M. 1958. Food habits of fishes and larger invertebrates of Lake Pontchartrain, Louisiana, an estuarine community. *Pub. Inst. Mar. Sci. Univ. Tex.*, (1958), 5: 353-416.

Dawson, C. E. 1958. A study of the biology and life history of the spot, *Leiostomus xanthurus* Lacepede, with special reference to South Carolina. *Contrib. Bears Bluff Lab.*, **28**: 1-48.

de Laubenfels, M. W. 1953. Sponges from the Gulf of Mexico. *Bull. Mar. Sci. Gulf Carib.*, **2**(3) : 511-557.

Florida State Board of Conservation. 1951. Composition of shrimp trawl catches. *Quarterly report on fisheries research by the Univ. of Miami.* March, 1951.

Garrick, J. A. F., Richard H. Backus, and Robert H. Gibbs, Jr. 1964. *Carcharhinus floridanus*, the silky shark, a synonym of *C. falciformis. Copeia*, 1964(2) : 369-375.

Ginsburg, I. 1951. Western Atlantic tonguefishes with descriptions of six new species. *Zoologica*, **36**(3) : 185-201 3 pls.

Gunter, G. 1938. Seasonal variations in abundance of certain estuarine and marine fishes in Louisiana, with particular reference to life histories. *Ecol. Monogr.*, **8**: 313-346.

1945. Studies on marine fishes of Texas. *Pub. Inst. Mar. Sci. Univ. Tex.*, **1**(1) : 1-190.

1950. Seasonal population changes and distributions as related to salinity, of certain invertebrates of the Texas Coast, including the commercial shrimp. *Pub. Inst. Mar. Sci. Univ. Tex.*, **1**(2) : 7-52.

1961. Salinity and size in marine fishes. *Copeia*, 1961 (2) : 234-235.

1963. Biological investigations of the St. Lucie estuary (Florida) in connection with Lake Okeechobee discharges through St. Lucie Canal, *Gulf Res. Repts.*, **1**(5) : 189-307.

Herald, E. S. and R. S. Strickland. 1949. An annotated list of the fishes of Homosassa Springs, Florida. *Quart. Journ. Fla. Acad. Sci.*, **11**(4) : 99-109.

Hildebrand, H. H. 1954. A study of the fauna of the brown shrimp (*Penaeus aztecus* Ives) grounds in the western Gulf of Mexico. *Publ. Inst. Mar. Sci. Univ. Tex.*, **3**(2) : 233-366.

Hildebrand, H. H. 1955. A study of the fauna of the pink shrimp (*Penaeus duorarum* Burkenroad) grounds in the Gulf of Campeche. *Pub. Inst. aMr .Sci. Univ. Tex.*, **4**(1) : 169-232.

Hildebrand, S. F. and L. E. Cable. 1930. Development and life history of fourteen teleostean fishes at Beaufort, N. C. *Bull. U. S. Bur. Fish.*, 46(1931: 383-488.

Joseph, E. B. and R. W. Yerger. 1956. The fishes of Alligator Harbor, Florida, with notes on their natural history. *Fla. St. Univ. Stud.*, **22**: 111-156.

Kilby, J. D. 1955. The fishes of two Gulf coastal marsh areas of Florida. *Tulane Stud. Zool.*, **2**(8) : 176-247.

Longley, W. H. and S. F. Hildebrand. 1941. Systematic catalogue of the fishes of Tortugas, *Carnegie Inst. Wash.*, Pub. 535: xii + 331, 34 pls.

Miles, R. M. 1951. An analysis o the "trash fish" of shrimp trawlers operating in Apalachicola Bay and the adjacent Gulf ,of Mexico. *M.S. Thesis, ,Fla. State Univ.*, iv + 1-46.

Moe, M. A. Jr. 1963. A survey of offshore fishing in Florida. *Fla. St. Bd. Conser.*, Prof. Pap. Ser. No. 4: 1-117.

Phillips, R. C. and V. G. Springer. 1960. Observations on the offshore benthic flora in the Gulf of Mexico off Pinellas County, Florida. *Amer. Mid. Nat.*, **64**(2) : 362-381.

Reid, G. K., Jr. 1954. An ecological study of the Gulf of Mexico fishes in the vicinity of Cedar Key, Florida. *Bull. Mar. Sci. Gulf & Carib.*, **4**(1) : 1-94.

Sand, R. F. 1959. Midwater trawl design by underwater observations. p. 209-212 in: Hilmar Kristjonsson, ed., *Modern fishing gear of the world.* Fishing News (Books) Ltd., London.

Scharfe, J. 1959. Experiments to decrease the towing resistance of trawl gear. p. 245-247. in: Hilmar Kristjonsson, ed., *Modern fishing gear of the world.* Fishing News (Books) Ltd., London.

Smith, ,F. G. Walton. 1953. The Gulf of Mexico sponge investigation. *Fla. St. Bd. of Conserv., Tech. Ser.*, 1:1-28.

Springer, S. and H. R. Bullis, Jr. 1956. Collections by the *Oregon* in the Gulf of Mexico. *U. S. Fish and Wildl. Serv., Spec. Sci. Rept.*, 196: 1-134.

Springer, V. G. 1961. Notes on and additions to the fish fauna of the Tampa Bay area. *Copeia*, 1961 (4) : 480-482.

Springer, V. G. and A. J. McErlean. 1962. Seasonality of fishes on a south Florida shore. *Bull. Mar. Sci. Gulf & Carib.*, 12 (1) : 39-60.

Springer, V. G. and K. D. Woodburn. 1960. An ecological study of the fishes of the Tampa Bay area. *Fla. St. Bd. of Conserv. Prof. Pap. Ser.* 1: 1-104.

Tabb, D. C. and R. B. Manning. 1961. A Checklist of the flora and fauna of northern Florida Bay and adjacent brackish waters of the Florida mainland collected during the period July, 1957, through September, 1960. *Bull. Mar. Sci. Gulf & Carib.*, **11**(4) : 552-649.

Whiteleather, R. T. 1948. Balloon trawl construction. *U. S. Dept. Int. Fish Leaf.*, No. 245: 3.

MBL WHOI Library - Serials
5 WHSE 02187